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12

ANALYSIS OF U.S. COAST GUARD HU-25A VISUAL AND RADAR DETECTION PERFORMANCE

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NOTICE

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This report is the sixteenth in a series which documents the Improved Probability of Detection in Search and Rescue (POD/SAR) Project at the USCG R&D Center.

16. Abstract

During February 1983, the U.S. Coast Guard R&D Center conducted an experiment in Fort Pierce, FL, to evaluate the visual and forward-looking airborne radar (FLAR) detection performance of a new Coast Guard medium-range surveillance aircraft, the HU-25A. Visual searches were conducted for small (13- to 18-foot) boats, orange-canopied life rafts (4- to 6-man), and simulated persons in the water (PIWs). FLAR searches were conducted for small boats with and without radar reflectors and for the canopied life rafts. Target and aircraft positions were monitored with a computer-based microwave tracking system for detection/miss range reconstruction accurate to better than 0.1 nautical mile.

The HU-25A was found to perform better as a visual search platform than other Coast Guard fixed-wing aircraft tested previously. Search speeds between 180 and 240 knots resulted in essentially uniform visual detection performance. The AN/APS-127 FLAR achieved cumulative detection probabilities between 11 and 50 percent in 1.5- to 4.5-foot seas and winds of 6 to 19 knots. Under these conditions, the FLAR system achieved initial detection ranges between 1.1 and 3.2 nautical miles.

Recommendations are made for HU-25A search operations and future evaluations.

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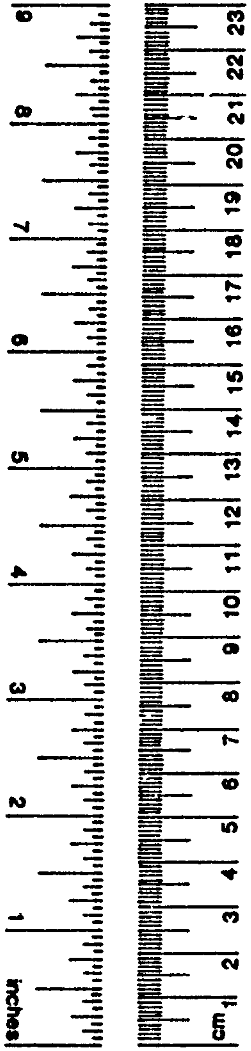
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

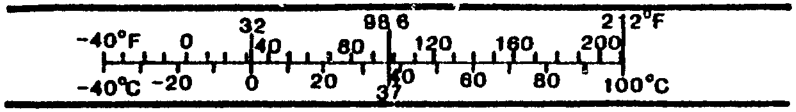
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25, SD Catalog No. C13.10 286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

1. Background

This report evaluates visual and forward-looking airborne radar (FLAR) detection performance of the U.S. Coast Guard HU-25A medium-range surveillance (MRS) jet aircraft. Data for this evaluation were collected during a February 1983 experiment conducted by the U.S. Coast Guard Research and Development (R&D) Center in Fort Pierce, Florida. This experiment was one of a series conducted by the R&D Center in support of the Improved Probability of Detection in Search and Rescue (POD/SAR) Project.

Visual searches were conducted for open, 13- to 18-foot white boats, 4- to 6-man orange-canopied life rafts, and simulated persons in the water (PIWs) with orange life jackets. FLAR searches were conducted for 13- to 18-foot open boats with and without radar reflectors and 4- to 6-man canopied life rafts without radar reflectors.

Data were analyzed to identify significant visual and FLAR search parameters (both environmental and system related) and to develop predictive models of detection performance.

2. HU-25A Systems Description

The HU-25A Guardian is a Falcon 20 jet aircraft modified especially for U.S. Coast Guard missions. Mission-related equipment includes large scanner windows and an AN/APS-127 FLAR system to aid in conducting search and rescue (SAR), law enforcement, and marine environmental protection surveillance. The SAR mission performance of the HU-25A was addressed during this experiment.

The AN/APS-127 FLAR is an X-band, dual-mode, surface search/weather radar developed by Texas Instruments, Inc., for the MRS aircraft. During data collection, the FLAR was operated in search mode from the avionicsman's console in the aft section of the aircraft.

RESULTS

1. HU-25A Visual Detection Performance

The HU-25A was found to be a better visual search platform than Coast Guard fixed-wing aircraft tested previously. This improvement is reflected in the sweep widths presented in Table 1. Variations in search speed between 180 and 240 knots resulted in no significant changes in visual detection performance.

2. AN/APS-127 FLAR Detection Performance

Increasing search altitude, increasing significant wave height (H_s), and the absence of a radar reflector were all found to significantly degrade AN/APS-127 FLAR detection performance. Cumulative detection probability (CDP)-versus-range curves for various combinations of these parameters are presented in Chapter 2. Comparison of these curves to those for AN/SPS-64(V) surface radar indicated that the FLAR achieved similar detection ranges but lower CDP.

CONCLUSIONS

1. The effects of environmental and aircraft-related search variables demonstrated in the HU-25A visual search data were consistent with the aircraft visual detection model developed by the R&D Center in 1981.

2. With 16-foot white boat and orange-canopied life raft targets, the HU-25A achieves visual detection performance superior to that of previously tested Coast Guard fixed-wing aircraft (HC-130, HC-131, and HU-16).

Table 1. Fixed-Wing Aircraft Sweep Width Comparison (16-foot white boat and orange-canopied life raft targets)

ENVIRONMENTAL CONDITIONS*	BASED UPON ANALYSIS OF FIXED-WING AIRCRAFT VISUAL DETECTION DATA	
	HU-25A	HC-130, HC-131, AND HU-16
Mean of conditions represented in HC-130 data subset (H_s = 1.3 ft, 40-percent cloud cover, wind speed = 11 knots)	-	2.6
Mean of conditions represented in HU-25A data subset (H_s = 2.6 ft, 50-percent cloud cover, wind speed = 11 knots)	3.7	-
Excellent search conditions (H_s = 0.5 ft, 0 cloud cover, wind speed $\leq$8 knots)	5.4	3.4
Poor search conditions (H_s = 4.0 ft, 100-percent cloud cover, wind speed = 18 knots)	2.1	0.9

*Assumed values of other significant search parameters are as follows for all four cases:

Visibility = 13 nautical miles

Search Speed = 200 knots

Time on Task = 1 hour

3. No significant variation in HU-25A visual detection performance results from searching at speeds between 180 and 240 knots for 16-foot white boat and orange-canopied life raft targets.

4. In 3.5- to 4.5-foot seas, the HU-25A achieves no better PIW detection performance than HC-130 and HC-131 aircraft.

5. AN/APS-127 FLAR detection performance achieved at an altitude of 300 feet was similar to that achieved at 500 feet in searches for small (<20-foot) boat and life raft targets. Searching at 1000 feet appears to increase sea return and degrade detection performance.

6. The AN/APS-127 achieves significantly better small-target CDP in light (~1.5-foot) seas than it does in rough (~3.5- to 4.5-foot) seas.

7. Fiberglass boats under 20 feet long without radar reflectors and 4- to 6-man rubber life rafts can be treated as similar FLAR targets by search planners. Use of a radar reflector on small boats significantly improves CDP but does not appear to increase maximum detection range.

8. Relative ocean wave direction and relative wind direction do not exert a clear influence on FLAR detection performance.

9. FLAR detection performance might have been better during the experiment if operators had been trained in methods for optimizing AN/APS-127 display effectiveness on small-target searches.

10. The clutter envelope processor (CEP) feature of the AN/APS-127 does not appear to be suitable for use during small-target searches.

OPERATIONAL RECOMMENDATIONS

1. As a conservative estimate of HU-25A visual search performance, search planners should use existing fixed-wing aircraft sweep width estimates as promulgated in previous POD/SAR Project reports and/or the upcoming revision to Chapter 8 of the National Search and Rescue Manual.

2. The visual detection performance prediction model for fixed-wing aircraft developed from past POD/SAR Project research should be modified to reflect the improved visual detection performance of the HU-25A once data required to precisely quantify this factor are collected.

3. During HU-25A searches for small boats, life rafts, or larger targets, speeds up to 240 knots should be selected on the basis of operational considerations such as aircraft range or fuel economy rather than detection performance.

4. When multiple searches of an area are required, search planners should offset fixed-wing aircraft search tracks approximately 0.2 nautical miles to compensate for a probable null area in scanners' field of view due to obstruction by the fuselage.

5. FLAR searches for small boats and life rafts should be conducted at altitudes of 500 feet or less.

6. The 5-nautical mile range scale of the AN/APS-127 should be used during small-target searches.

7. The CEP feature of the AN/APS-127 should not be used during searches for small (<20-foot) boats and life rafts unless the FLAR operator can obtain visual confirmation while enroute to the search area that its use is not eliminating similar targets.

8. Training in AN/APS-127 small-target search techniques should be provided to all FLAR operators.

RECOMMENDED FUTURE RESEARCH

1. Additional HU-25A visual detection data should be collected (using small-boat and life raft targets) in a wind wave-dominated environment such as Block Island Sound. These data should be used to quantify more precisely the improvement in visual detection performance achievable with the HU-25A.

2. HU-25A visual detection data should be collected in light (<2-foot) sea conditions with PIW targets to provide a meaningful basis for comparing HU-25A PIW detection performance with that of other Coast Guard aircraft.

3. If additional visual detection data are collected using fixed-wing aircraft, some targets should be placed within 0.1 nautical mile of the intended search track. This would provide data to better quantify any degradation in P(x) due to fuselage obstruction of scanners' fields of view.

4. Future FLAR evaluations should be conducted using operators with specific training in small-target search techniques or, as a minimum, using highly specific instructions as to PPI display set-up requirements.

5. To ensure consistent performance during future evaluations, the FLAR system should be checked daily to ensure it is operating within specifications.

6. Small-target detection data should be collected using the AN/APS-127 in ground-stabilized mode to determine if it improves detection performance in spite of increased operator workload.

CHAPTER 1
BACKGROUND

1.1 SCOPE

This report details an evaluation of the visual and forward-looking airborne radar (FLAR) search performance of the Coast Guard HU-25A Guardian medium-range surveillance (MRS) aircraft. The data used in this evaluation were collected during an experiment conducted by the U.S. Coast Guard Research and Development Center (R&D Center) in the Atlantic Ocean off Fort Pierce, Florida, during February, 1983. Targets included 13- to 18-foot fiberglass boats, life rafts, and simulated persons in the water (PIWs).

This experiment was one of a series conducted by the R&D Center since 1978 in support of the project, Improvement in Probability of Detection (POD) in Search and Rescue (SAR). Project objectives are to:

a. Improve visual search effectiveness,
b. Evaluate and quantify the detection performance of electronic sensors,
c. Support the development of a more accurate POD model,
d. Improve leeway drift prediction methods, and
e. Determine detection ranges of visual distress signalling devices.

The objectives of this particular experiment were to evaluate the visual and electronic detection performance of the HU-25A and to test a new forward-looking infrared system (FLIR). Only the first objective is addressed in this report.

1.2 HU-25A SYSTEM DESCRIPTION

The HU-25A Guardian is a Falcon 20 jet aircraft specially modified to perform the medium-range surveillance missions of the U.S. Coast Guard.

These missions include SAR, law enforcement, fisheries patrol, and marine environmental protection. The HU-25A replaces the HU-16E Albatross and HC-131 Convair aircraft in this role.

For visual search, two large rectangular scanner's windows are located aft of the cockpit but forward of the swept-back wings. Three-way adjustable seats are provided at these windows for scanner positioning and comfort. The pilots' fields of view are the same as in the standard Falcon 20, with segmented windows and adjustable seat height. The aircraft is pressurized and air conditioned, with in-flight noise levels significantly lower than those of the Albatross and Convair. These overall improvements in crew comfort are expected to reduce fatigue during visual search missions.

The HU-25A tested during this experiment was equipped with the AN/APS-127 FLAR. This sensor is an X-band, dual-mode, surface search/weather radar developed by Texas Instruments, Inc., for the U.S. Coast Guard MRS aircraft. Primary controls for the AN/APS-127 are located on the avionicsman's console in the rear of the aircraft. Two FLAR displays are provided on the HU-25A: a 5-inch azimuth range indicator (ARI) in the cockpit designed primarily for operation in the weather radar mode and a 7-inch plan position indicator (PPI) on the avionicsman's console designed primarily for operation in the search mode. Selectable special features of this system include sea-clutter envelope processing (CEP), antenna tilt, frequency agility, long or short pulse mode, and heading/north/ground stabilization. Range scales are selectable from 5 to 160 nautical miles with the option of moving the display origin from its normal centered position to any location on the PPI. A detailed AN/APS-127 system description can be found in Reference 1. All FLAR data for tne evaluation were collected using the avionicsman's console.

1.3 EXPERIMENT DESCRIPTION

1.3.1 Participants

The primary search aircraft was HU-25A number 2110 from the Coast Guard Aircraft Repair and Supply Center, Elizabeth City, North Carolina. During the experiment, CG2110 was based at Air Station Miami, Florida, and flown by Miami aircrews. HU-25A number 2111 provided visual search support on one day of the experiment when CG2110 was unavailable. A total of 10 days of HU-25A aircraft time was provided for data collection. During this time, 11 visual search sorties were flown on 7 days and 4 FLAR search sorties were flown on 3 days. Typical visual search sorties involved 1.2 to 1.9 hours of actual search time, while typical FLAR sorties involved approximately 2 hours of actual search time. In addition to the HU-25A flights, Coast Guard helicopter number 1379 (an HH-52A from Air Station Miami) conducted FLIR searches which have been reported on in a separate letter (Reference 2).

Coast Guard Station Fort Pierce, Florida, provided communications support, docking facilities, and shore facilities for the on-scene monitor vessel and R&D Center equipment. Station Fort Pierce also provided the services of one of its 41-foot utility boats (UTBs) when needed for target deployment and retrieval.

The Coast Guard R&D Center provided tracking equipment, targets, and other logistics support to the POD/SAR Field Team, which controlled the experiment.

Florida Institute of Technology (FIT) was contracted by the R&D Center to provide its 42-foot research vessel, JENNY D, for on-scene monitoring and target deployment/retrieval during the experiment. JENNY D was skippered by FIT personnel and manned by a Coast Guard crew.

1.3.2 Exercise Area

Searches were conducted in the Atlantic Ocean off Fort Pierce, Florida, in a 15- by 30-nautical mile area centered at 27° 32.6'N, 80° 09.0'W with a major axis of 162 degrees magnetic (see Figure 1-1). Actual search areas assigned to the aircraft depended upon specific data-collection objectives, target type, and the sensor being tested.

1.3.3 Experiment Design and Conduct

Visual searches were conducted in the same manner as actual SAR missions. Parallel searches (PS) (see Figure 1-2) were executed as prescribed in Chapter 8 of the National Search and Rescue Manual (Reference 3). Targets were placed randomly within the search area and moved periodically by the monitor vessel to prevent biasing the data because of crew alertment to target positions. Every effort was made during these searches to maintain realistic crew motivation levels and utilize standard SAR mission procedures. The only exception to this policy was that, when a possible target was reported by the aircrew, no deviation from the intended search track was made to investigate the sighting. All target sightings were recorded by an onboard R&D Center observer and verified during post-experiment analysis of data logs and searcher/target position plots.

FLAR searches were conducted along straight tracklines for targets that were set at intervals of 4 to 5 nautical miles. These detection runs were designed to collect data for developing cumulative detection probability-versus-range (CDP) curves as described in Reference 4. During the detection runs, the FLAR operator was semi-alerted; that is, he had some knowledge of where and when to expect radar contacts to occur. This approach was necessary to eliminate a large number of extraneous targets (primarily sport fishing vessels) from consideration and provides an upper bound on estimates of operational system performance. Subjective observations made during previous CDP experiments have indicated that this semi-alertment does not significantly alter operator behavior.

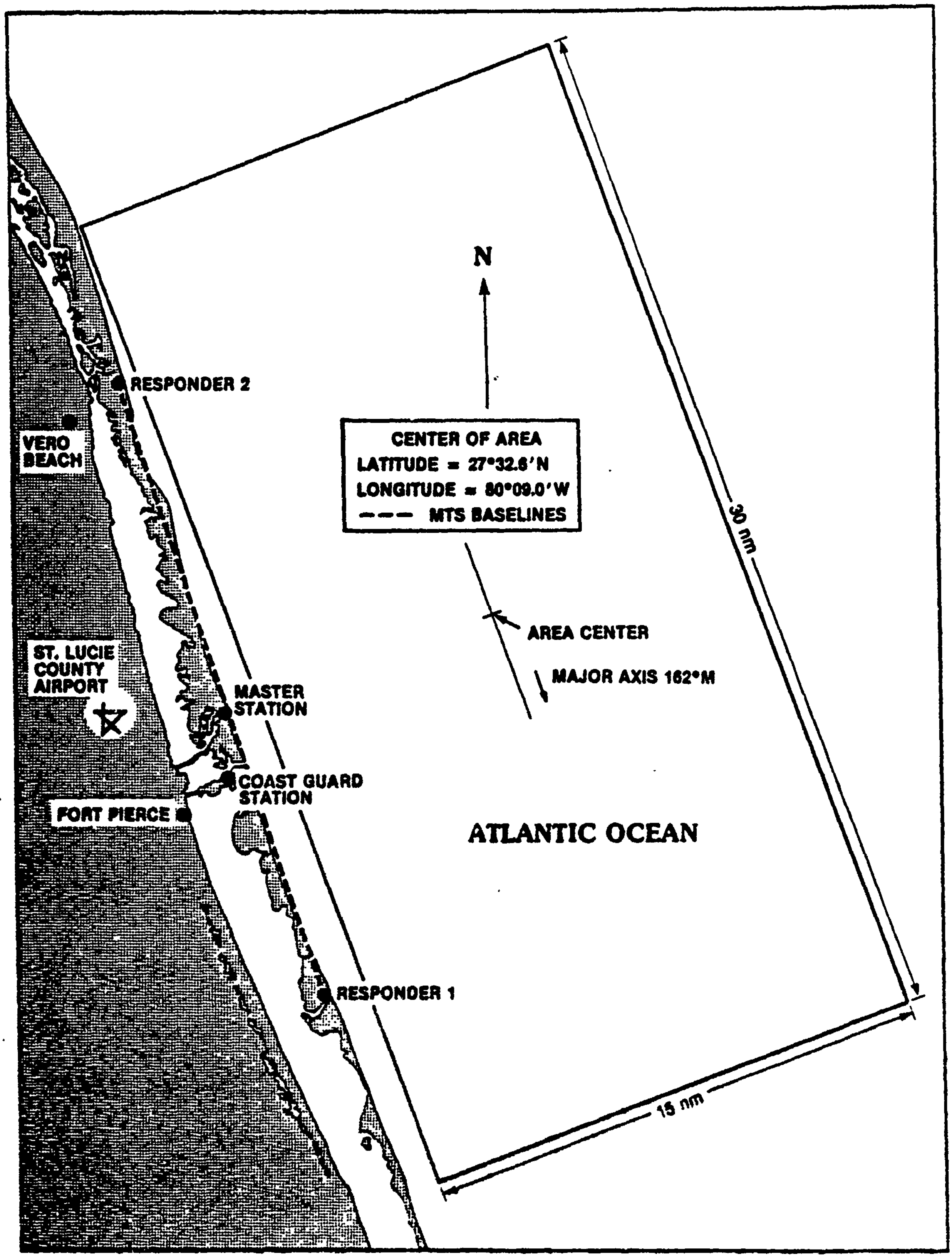
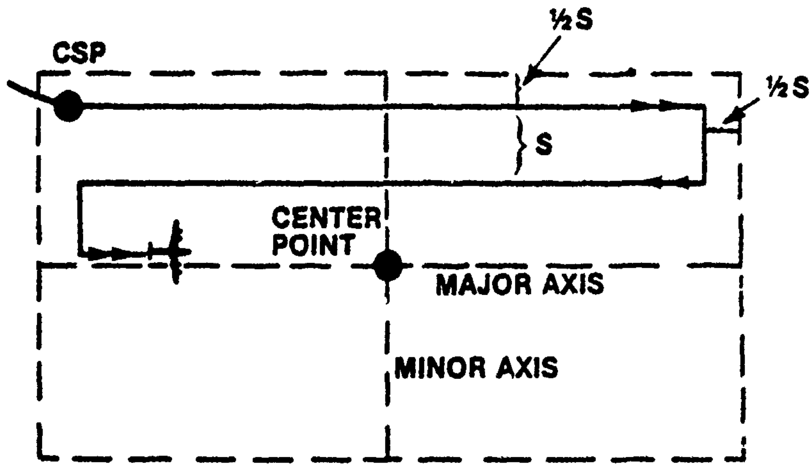


Figure 1-1. Exercise Area



NOTE: SEARCH LEGS WERE PARALLEL TO THE DIRECTION OF THE MAJOR AXIS OF THE SEARCH AREA AND WERE SEPARATED BY A SPECIFIED TRACK SPACING. COMMENCE SEARCH POINTS (CSP) AND OUTER SEARCH LEGS WERE ONE-HALF THE TRACK SPACING (S) INSIDE THE PERIMETER OF THE SEARCH AREA.

Figure 1-2. Parallel Search Pattern

The range and bearing of initial target detection were reported to the onboard observer, and visual confirmation of each reported contact was attempted by the aircrew as an aid to data analysis. FLAR operators were two ATs from Coast Guard Air Station Miami with no special training in how to use the AN/APS-127 as an SAR sensor. One operator had about 20 hours of prior experience with the AN/AP-127; the other had about 35 hours. None of this prior experience included structured searches for small targets.

For data collection, the AN/APS-127 was operated with the following features selected (occasional brief exceptions occurred):

PULSE - SHORT
FREQUENCY - FIXED
MODE - SEARCH
ANTENNA TILT - 0 to -3 degrees (as required)
CEP - OFF (tended to eliminate targets)
STABILIZATION - HEADING
RANGE SCALE - 5 nautical miles with origin displaced to bottom of PPI for an effective 10-nautical mile display.

Intensity, gain, and persistence controls were generally set as recommended for small target search in Reference 1, but the operators tended to make frequent adjustments to these parameters. Specific operator training and experience in small-target search techniques probably would have improved display consistency and, possibly, detection performance.

Figure 1-3 illustrates the search pattern used during FLAR searches. Search legs were aligned so that target detection opportunities occurred in the down-sea, up-sea, and cross-sea directions. This methodology was designed to identify the effect, if any, of relative ocean wave direction on FLAR detection performance. Each leg of the search pattern was begun at a distance well beyond the expected initial detection range for the first target on that leg, ensuring that maximum target detection range could be identified.

Visual and FLIR searches were sometimes conducted concurrently due to similarities in search design. FLAR searches, because of their unique design, were always conducted independently of other data-collection efforts.

1.3.4 Targets and Radar Reflectors

Visual searches were conducted for anchored 13- to 18-foot, white, unmanned, open boats, 4- to 6-man orange-canopied life rafts, and simulated persons in the water (PIWs) with orange life jackets. Small boats and life rafts were usually searched for concurrently in a 16- by 30-nautical mile search area. PIWs were usually searched for in a 6- by 20-nautical mile area without other targets present. The number of targets set in the search area varied from day to day and even over the course of a single day, typically ranging from four to seven.

FLAR searches were conducted for anchored 13- to 18-foot open fiberglass boats without engines or other substantial metal equipment, similar fiberglass boats with a 5-foot wooden post and radar reflector, and 4- to 6-man

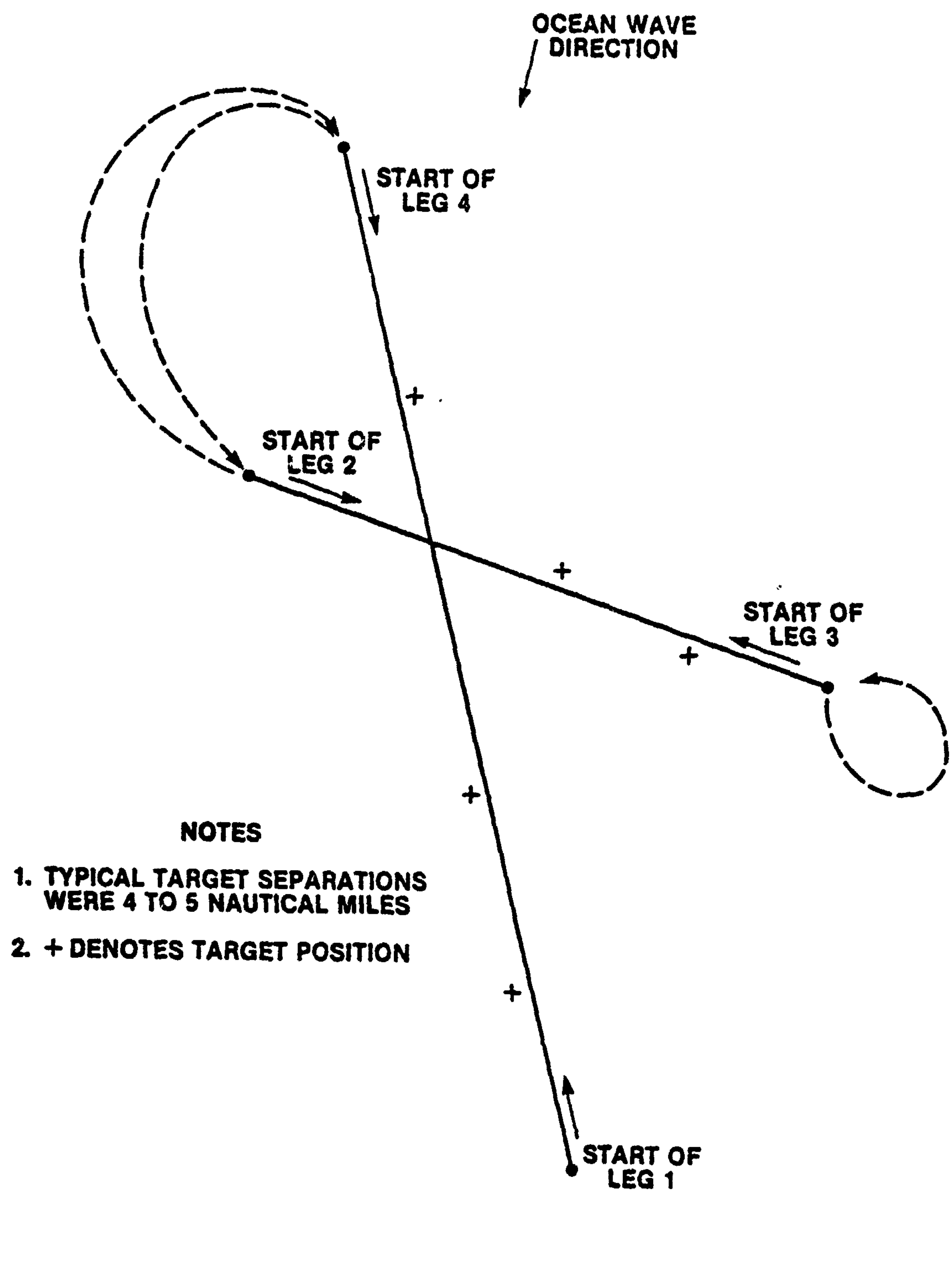


Figure 1-3. Example of FLAR Search Pattern Used for Detection Runs

canopied rubber/fabric life rafts without radar reflectors. Five targets (usually three life rafts and two boats) were set on two search legs for most FLAR searches.

Table 1-1 summarizes the target types used during the experiment and the total number of visual and FLAR detection opportunities that occurred with each type.

1.3.5 Environmental Conditions

Environmental conditions ranged from fair to excellent during the experiment on days when data were collected. Wave heights were in the 3- to 5-foot range more often during this experiment than in other POD/SAR

Table 1-1. Summary of Target Opportunities

SEARCH TYPE	TARGET DESCRIPTION	NUMBER OF DETECTION OPPORTUNITIES
VISUAL AREA SEARCHES	13- to 18-foot fiberglass boat (white)	61
	4- to 6-man orange-canopied life raft	97
	PIW with orange life jacket	78
FLAR TRACKLINE RUNS	13- to 18-foot fiberglass boat without radar reflector	26
	13-foot fiberglass boat with Davis Echomaster Deluxe radar reflector (12.5-inch octahedral cluster of circular almuminum reflector plates)	2
	13- to 18-foot fiberglass boat with Radark folding radar reflector aluminum tetrahdron)	12
	4- to 6-man canopied rubber fabric life raft without radar reflector	35

Project experiments, but remained within a range of values where a valid comparison between the search performance of the HU-25A and other Coast Guard fixed-wing aircraft could be made. Table 1-2 summarizes the range of environmental conditions encountered during the visual and FLAR search exercises.

1.3.6 Tracking and Reconstruction

Target locations and search unit positions were monitored using an automated Microwave Tracking System (MTS) consisting of a Motorola MiniRanger III mobile tracking system coupled with a Hewlett-Packard 9845B mini-computer and model 9872A plotter. This system was developed by the Coast Guard R&D Center for the POD in SAR Project to provide target position and search track reconstruction accurate to better than 0.1 nautical mile. Its operation is described in detail in Reference 5.

The MTS master station was located on the roof of the Sea Palms condominiums in Fort Pierce. Two secondary stations were located in Vero Beach (to the north) and Stuart (to the south). These locations, which facilitated line-of-sight tracking of searcher and target positions, are depicted in Figure 1-1.

Table 1-2. Range of Environmental Parameters

PARAMETER OF INTEREST	VISUAL SEARCHES FOR SMALL BOATS AND LIFE RAFTS		VISUAL SEARCHES FOR PIWs		FLAR SEARCHES	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Wind Speed (knots)	0	16	12	18	5	19
Significant Wave Height (ft)	1.0	4.0	3.0	4.0	1.5	4.5
Precipitation	N/A	N/A	N/A	N/A	None	None
Relative Humidity (percent)	N/A	N/A	N/A	N/A	52	76
Cloud Cover	0.1	0.9	0.0	0.9	N/A	N/A
Visibility	12	15+	15	15+	N/A	N/A

Target positions were marked by the on-scene monitor vessel(s) (equipped with MTS transponders) when the targets were first anchored, and again when they were picked up. Positions of transponder-equipped search units were monitored continuously by the MTS and recorded on magnetic tape every 10 to 30 seconds. Outputs of the MTS included a real-time CRT display of the search area, target positions, and search unit track; a hard copy of searcher, target, and monitor vessel positions; and an 11- by 17-inch position/time plot of each search. An example of the real-time MTS display is shown in Figure 1-4.

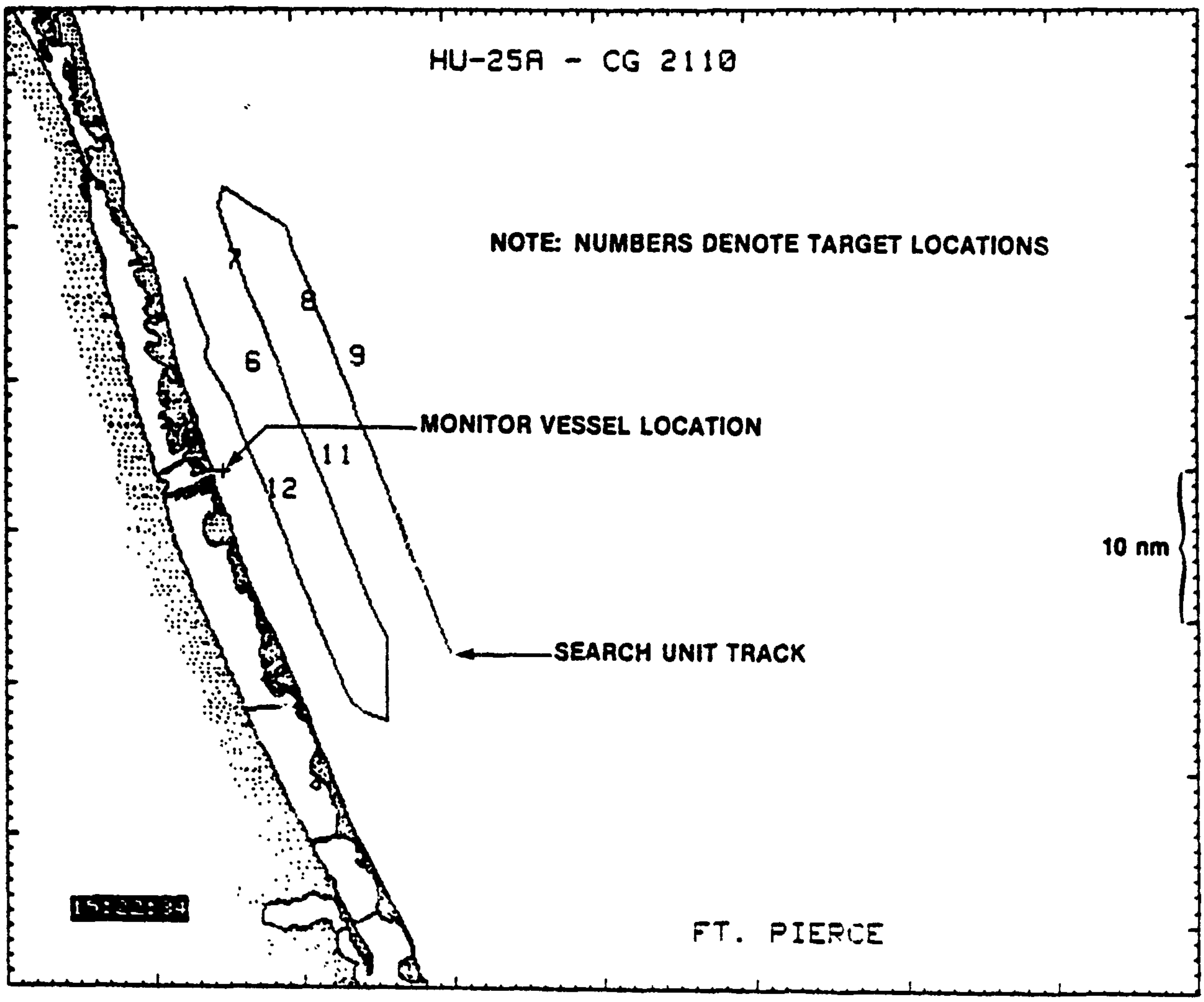


Figure 1-4. Example of MTS Real-Time Display

Detection and closest point of approach (CPA) ranges were determined for each target opportunity by referring to detection logs kept by the observer onboard each search unit and MTS position/time plots. When the range and relative bearing of a contact reported by the radar operator or visual scanner (as appropriate) agreed with the MTS plot, a target detection was recorded. Actual detection ranges were measured on the MTS plot directly from the search unit's trackline position at time of contact to the target position. CPA ranges were measured from the target to the nearest point on the search unit trackline.

1.4 ANALYSIS APPROACH

1.4.1 Measures of Search Performance

Two measures of search performance were used to evaluate the visual and FLAR data. Visual search performance was evaluated by computing sweep widths achieved by the HU-25A for various combinations of significant search parameters. These sweep widths were compared to those achieved by other Coast Guard fixed-wing aircraft during earlier R&D Center experiments. FLAR detection performance was evaluated by calculating CDP as a function of range to the target for various combinations of target type, search altitude, and environmental conditions. The two subsections that follow describe sweep width and CDP in detail.

1.4.1.1 Sweep Width

The primary performance measure currently utilized by SAR mission coordinators to plan visual searches is sweep width (W). Sweep width is a single-number summation of a more complex range/detection probability relationship. Mathematically,

$$\text{Sweep Width (W)} = \int_{-\infty}^{\infty} P(x)dx,$$

where

x = lateral range or closest point of approach to targets of opportunity (see Figure 1-5) and

P(x) = probability of detection at lateral range x.

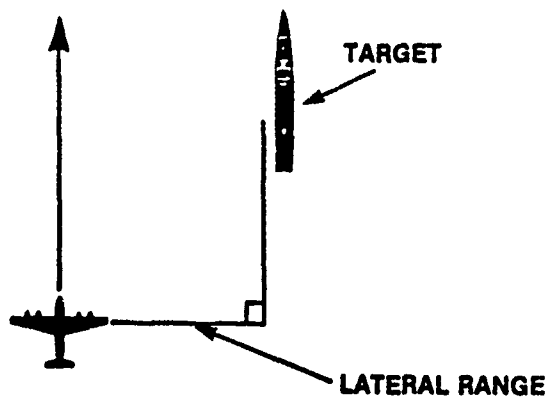


Figure 1-5. Definition of Lateral Range

Figure 1-6 shows a typical P(x) curve as a function of lateral range. In Figure 1-6, (x) is the lateral range of detection opportunities.

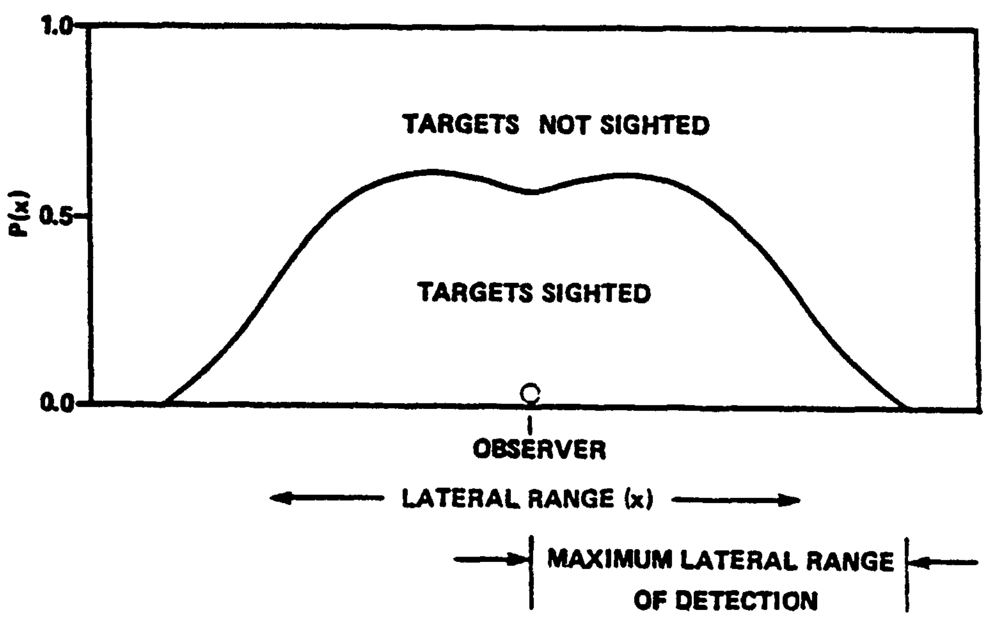


Figure 1-6. Relationship of Targets Sighted to Targets Not Sighted

Conceptually, sweep width is the numerical value obtained by reducing the maximum detection distance of any given sweep so that scattered targets which may be detected beyond the limits of W are equal in number to those which may be missed within those limits. Figure 1-7 (A and B) graphically presents this concept of sweep width. The number of targets missed inside the sweep width distance is indicated by the shaded portion near the top middle of the rectangle (area A), while the number of targets sighted beyond the sweep width distance out to maximum detection range (R_D) is indicated by the shaded portion at each end of the rectangle (area B). Referring only to the shaded areas, when the number of targets missed equals the number of targets sighted (area A = area B), sweep width is defined. A detailed mathematical development and explanation of sweep width can be found in Reference 6.

From literature research, 25 parameters have been identified as having a potential influence on visual sweep width. These parameters can be divided into three categories:

1. Primary, independent measurable parameters,
2. Interdependent human factors, and
3. Secondary parameters.

Primary variables are those that have been investigated during the series of POD/SAR Project visual detection experiments. They are:

1. SRU type,
2. Target type (size, shape, and color),
3. Meteorological visibility*,

---

* Meterological visibility is defined as the maximum range at which a large object can be distinguished. This parameter has been used in POD/SAR Project experiments to be consistent with the National SAR Manual and to avoid using subjective measurement, such as effective visibility. When used in this report, "visibility" refers to "meteorological visibility."

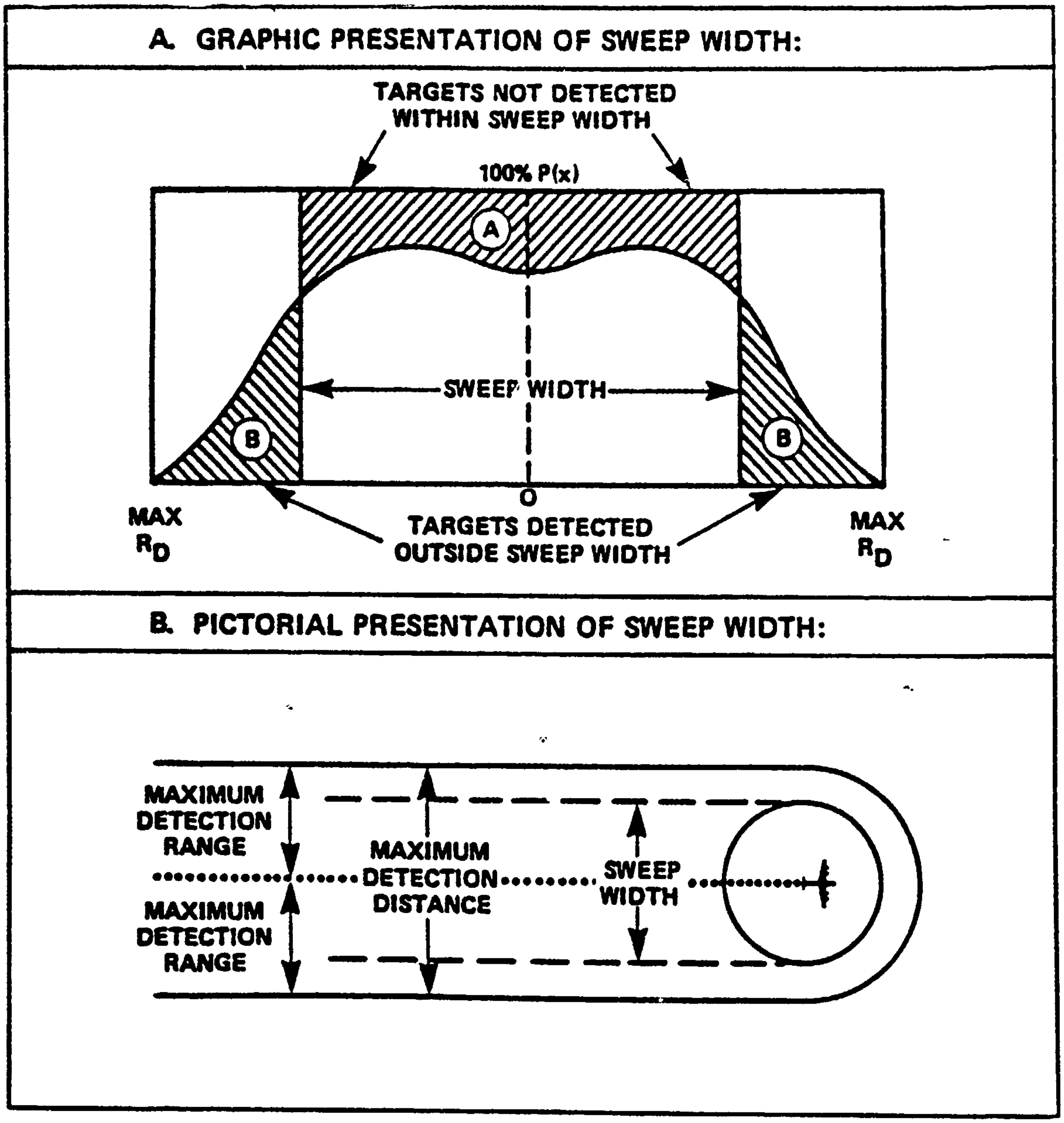


Figure 1-7. Graphic and Pictorial Presentation of Sweep Width

4. Altitude,
5. Search speed,
6. Time on task,
7. Wind speed,
8. Sun's elevation,
9. Significant wave height (H_s)*, and
10. Cloud cover.

These same variables were recorded during this experiment. Variables previously found to influence aircraft visual search performance were analyzed to determine their effects on HU-25A visual search performance. Human factors and secondary variables are discussed in Reference 5 and will be addressed only subjectively in this report.

1.4.1.2 Cumulative Detection Probability

Cumulative detection probability as a function of range is a useful measure of sensor detection performance. CDP provides a better picture of how target detection probability increases as sensor-to-target range closes than do detection range statistics alone. CDP computation considers targets missed as well as those detected. Simply stated, CDP is defined as the probability that a target will have been detected by the time it closes to a given range; it is a monotonically increasing function of closing range.

Figure 1-8 illustrates the CDP-versus-range function for a typical radar. The slope of the CDP curve is steepest over the range interval where most detections occur. Horizontal portions of a CDP curve indicate range intervals where no additional targets are detected. It is quite common for a radar CDP curve to exhibit a horizontal segment at very close range where

* Significant wave height is approximately the height an experienced observer will give when visually estimating the height of waves at sea.

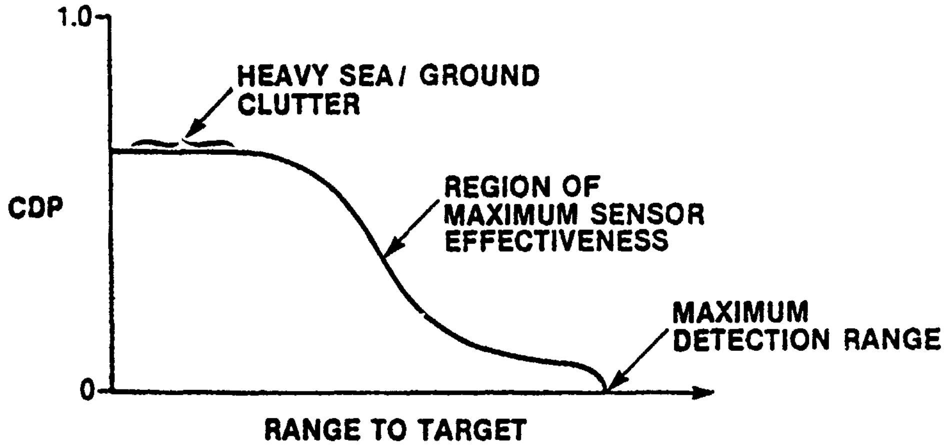


Figure 1-8. Typical CDP-versus-Range Curve for Radar

heavy sea clutter or ground return masks targets. The reader will note that CDP curves are not to be confused with lateral range curves and cannot be used to directly compute sweep width as discussed in the previous section of this report.

CDP curves have been used in previous POD/SAR Project analyses to evaluate surface vessel radar (SVR) and FLIR detection performance. A comparison between FLAR and SVR CDP curves is made in Chapter 2.

1.4.2 Analysis of Visual Search Data

Two primary questions were addressed in the HU-25A visual detection data analysis. They were:

1. Is there a significant difference in visual detection performance between the HU-25A and older Coast Guard fixed-wing aircraft (especially the HC-130, which will continue to be used for SAR missions)?

2. Does searching at speeds of about 240 knots (best HU-25A range capability-most trackline miles per load of fuel) degrade visual search performance unacceptably compared to speeds of about 180 knots (near HU-25A minimum safe search speed)?

The influence of and interactions among search parameters, aircraft type, search speed, and other variables found to be significant in the 1981 visual detection study (Reference 5) were investigated using a sophisticated binary, multivariate regression analysis technique (LOGODDS).

The linear logistic (LOGODDS) model was selected as an appropriate analysis tool for fitting POD/SAR Project visual search data where the dependent variable is binary (i.e., detection/no detection). The LOGODDS model is useful in quantifying the relationship between independent variables (x_i) and a probability of interest, R (in this case the probability of detecting a target). The independent variables (x_i) can be continuous (e.g., range*, search speed, wind speed) or binary (e.g., day/night, black/orange, SRU type 1 or 2). The LOGODDS model has been used with great success in previous POD/SAR Project visual search performance analyses. It was used in this analysis because of its proven analytical power and compatiblity with previous Project data.

The equation that the model uses for target detection probability is:

$$R = \frac{1}{1 + e^{-\lambda}}$$

* In developing the P(x)-versus-lateral range curve, range is determined by the closest point of approach that a search and rescue unit (SRU) comes to a target of opportunity and is called lateral range. Since the distance between SRU and target is not affected by the primary variables being investigated, it is considered independent.

where

$$\lambda = a_0 + a_1x_1 + a_2x_2 + a_3x_3.....$$

a_i = constants (determined by computer program) and

x_i = independent variable values.

The LOGODDS model has the following advantages over other candidate models/techniques:

1. The model implicitly contains the assumption that $0 \leq R \leq 1.0$. A linear model does not, unless the assumption is added to the model (and then computation can become exceedingly difficult).

2. The model is analogous to normal-theory linear models. Thus, analysis of variance and regression implications can be drawn from the model.

3. The model can be used to observe the effects of several independent or interactive parameters be they continuous or discrete.

4. A regression technique is better than non-parametric hypothesis testing which does not yield quantitative relationships between the probability in question and values of the independent variables.

The primary disadvantages of the LOGODDS model are:

1. For the basic models, the dependent variable (R) must be a monotonic function of the independent variables.

2. The computational effort is substantial, requiring use of computer techniques.

Appendix A of Reference 7 provides a more detailed description of the LOGODDS model.

Variables (in addition to lateral range) included in the LOGODDS data analysis for this experiment were those that had previously been found to have significant influence on fixed-wing aircraft visual search peformance (Reference 5). These variables were:

1. Wind speed,
2. Significant wave height,
3. Time on task,
4. Meteorological visibility,
5. Cloud cover,
6. Search speed, and
7. Target type (16-foot boats and orange-canopied life rafts were treated separately from PIWs).

In addition, aircraft type (i.e., HU-25A versus HC-130, HC-131, and/or HU-16) was included as a variable to answer question 1, mentioned earlier. Search altitude and sun elevation, while recorded, were confined to a narrow range of values during this experiment because they demonstrated no strong influence on aircraft visual search performance in previous analyses.

1.4.2.1 Development of Raw Data

Valid sightings of SAR targets were determined by comparing sighting reports (maintained by observers onboard SRUs) to the reconstructed search plots. For each sighting recorded, the time of the sighting and the estimated target range and relative bearing were compared to actual target positions. If a sighting was determined to be a valid detection, the lateral range and values of other explanatory variables were recorded. The maximum lateral range of detection for the aircraft on the day in question was determined. This value was multiplied by 1.5, and became the criterion for determining targets of opportunity (maximum lateral range for the aircraft on

the day tested). A multiplier of 1.5 was selected to provide sufficient data to identify the maximum detection range (MDR) without adding a large number of meaningless (long-range) misses. Any target whose lateral range was less than or equal to 1.5 times the maximum lateral range of valid detections and was not recorded as a sighting was determined to be a "miss." The lateral range and other explanatory variables for all targets of opportunity (detection or miss) were recorded in the same manner. Thus, a separate raw data file was developed for each search day that included all valid target sightings and all misses that met the criterion above. Raw visual search data for this experiment are included in Appendix A.

1.4.2.2 Validation of LOGODDS Model Fit

Once the computer runs had been conducted to develop the LOGODDS model, a "goodness of fit" test was performed to evaluate the model. Empirical data were binned by lateral range and other significant parameters to compare, in a qualitative sense, the goodness of fit of the model to experimental data (one such plot is shown in Figure 2-1). In all cases these results were satisfactory. Also, a LOGODDS subroutine performed a Chi-squared test of the goodness of model fit to empirical data. The results of these tests indicated that the model with significant explanatory variables explained observed variation in P(x) at the 0.01 level of significance.

In addition, Chi-squared tests were conducted to determine whether the LOGODDS model with only those variables determined to be significant could be improved upon by the addition of other explanatory variables. In no case did Chi-squared tests at a 0.01 level of significance indicate that a significantly better model fit would result by the addition of other explanatory variables.

The goodness of fit of the model to the empirical data was also checked through an analysis of residuals (residuals are defined as the difference between the model prediction of P(x) and the outcome for each observation). Three different analyses of residuals were conducted:

1. The overall distribution of the residuals was checked for a near zero mean and normality.

2. Residuals were plotted with respect to each significant independent variable to check for systematic deviations from the model predictions.

3. Residuals were plotted with respect to predicted probabilities and aggregated to allow for analysis of variance.

Once satisfactory lateral range curves were generated using the LOGODDS model, sweep widths for various combinations of significant parameters were calculated by numerical integration.

1.4.3 Analysis of FLAR Detection Data

Based upon previous POD/SAR Project radar studies, literature research, and operational considerations, five primary objectives were addressed in the FLAR data analysis. They were to:

1. Develop the CDP-versus-range relationships for the AN/APS-127 searching for small boat and life raft targets.

2. Determine the best range of search altitude for small-target searches.

3. Determine the influence of significant wave height on AN/APS-127 small-target detection performance.

4. Determine whether rubber life rafts and small fiberglass boats without reflective equipment should be treated as different target types. Determine whether reflectors improve the detectability of small, non-metal targets by FLAR.

5. Determine if the aircraft's orientation relative to the direction of major ocean waves and/or surface wind has a significant influence on detection performance.

Since only three days of FLAR search were conducted (a total of four sorties), the small size of the data base did not lend itself to answering these questions by generating CDP curves for highly specific sets of search parameters. A simple means of determining which parameters exerted a significant influence on FLAR detection performance was necessary so that fragmentation of the data would be minimized when developing CDP curves. To make this determination, the raw FLAR data (included as Appendix B) were sorted by search altitude, significant wave height, relative wave direction, and target type. For each data subgroup, mean target detection range and percent of targets detected were computed as rough indicators of radar performance. These indicators were compared using a computer routine which performs two-way analysis of variance for unbalanced data (Reference 8) to identify which variable(s) exerted statistically significant influences on either or both performance indicators.

Once the initial determination of significant variables was made, the FLAR detection data were sorted into appropriate groups for CDP curve generation. CDP curves that illustrate the influence of significant variables on AN/APS-127 small-target detection performance, and that support conclusions relative to the four questions posed earlier, appear in Chapter 2. A detailed description of the computer algorithum used to generate these CDP curves appears in Appendix B of Reference 9.

CHAPTER 2
RESULTS

2.1 INTRODUCTION

This chapter is divided into two sections: Visual Search Performance and FLAR Detection Performance. The section on visual search performance discusses significant search parameters identified during data analysis and presents LOGODDS-generated lateral range curves and sweep widths for representative conditions. The FLAR detection performance section discusses the effects of search parameters on detection performance, presents CDP curves for the AN/APS-127, and compares results to those obtained during earlier tests by the Navy (Reference 10). A comparison of AN/APS-127 detection peformance with that of the AN/SPS-64 surface search radar is also made.

2.2 VISUAL SEARCH PERFORMANCE

As mentioned in Section 1.4.2, the two primary objectives to be addressed in the analysis of visual search data were: (a) to identify any differences in visual search performance between the HU-25A and older fixed-wing aircraft and (b) to determine whether higher (240-knot) search speeds significantly reduced visual search performance from that attainable at lower (180-knot) search speeds.

2.2.1 Visual Detection of Small Boats and Life Rafts

In order to address the two primary analysis objectives, visual search data collected during previous experiments using HC-130 aircraft flying at 180 to 200 knots were combined with HU-25A visual search data. Initially, only data collected at search altitudes of 1000 and 1500 feet using white 16-foot boat and orange-canopied life raft targets were analyzed. This approach reduced the potential for spurious effects (from parameters not of

primary interest) to bias results while the two key questions were being addressed. This data subset, consisting of 124 HC-130 and 148 HU-25A detection opportunities, comprised about one third of the total fixed-wing aircraft visual detection data available, including nearly all of the HU-25A data.

Variation in target detection probability [P(x)] was explained at the 0.01 level of significance for these data by a combination of the following variables:

1. Lateral range,
2. Aircraft type,
3. Significant wave height (H_s), and
4. Cloud cover.

Variables found not to have a significant influence on P(x) <u>with this limited data subset</u> were wind speed, time on task, visibility, and search speed. Search altitude, sun elevation, and target type were not included in this analysis because they were confined to a narrow range of values as discussed in Chapter 1.

Lateral range was the most influential parameter in explaining variation in target detection probability. This result is consistent with all previous POD/SAR Project visual detection analyses. Aircraft type was the second most influential variable, with the HU-25A performing significantly better than the HC-130. Figure 2-1 illustrates the influence of lateral range and aircraft type on P(x). The LOGODDS regression fit and empirical data demonstrate good agreement at all lateral ranges represented except for the 0.0- to 0.1-nautical mile interval. The six detection opportunities that occurred within this lateral range interval resulted in only one detection, indicating a possible null region close-aboard the aircraft due to the fuselage blocking scanners' fields of view. This slight discrepancy between empirical data and model fit, if validated by additional data in the future, would result in less than 0.2-nautical mile errors in sweep width calculations even under ideal search conditions. If greater accuracy is desired, the difference can

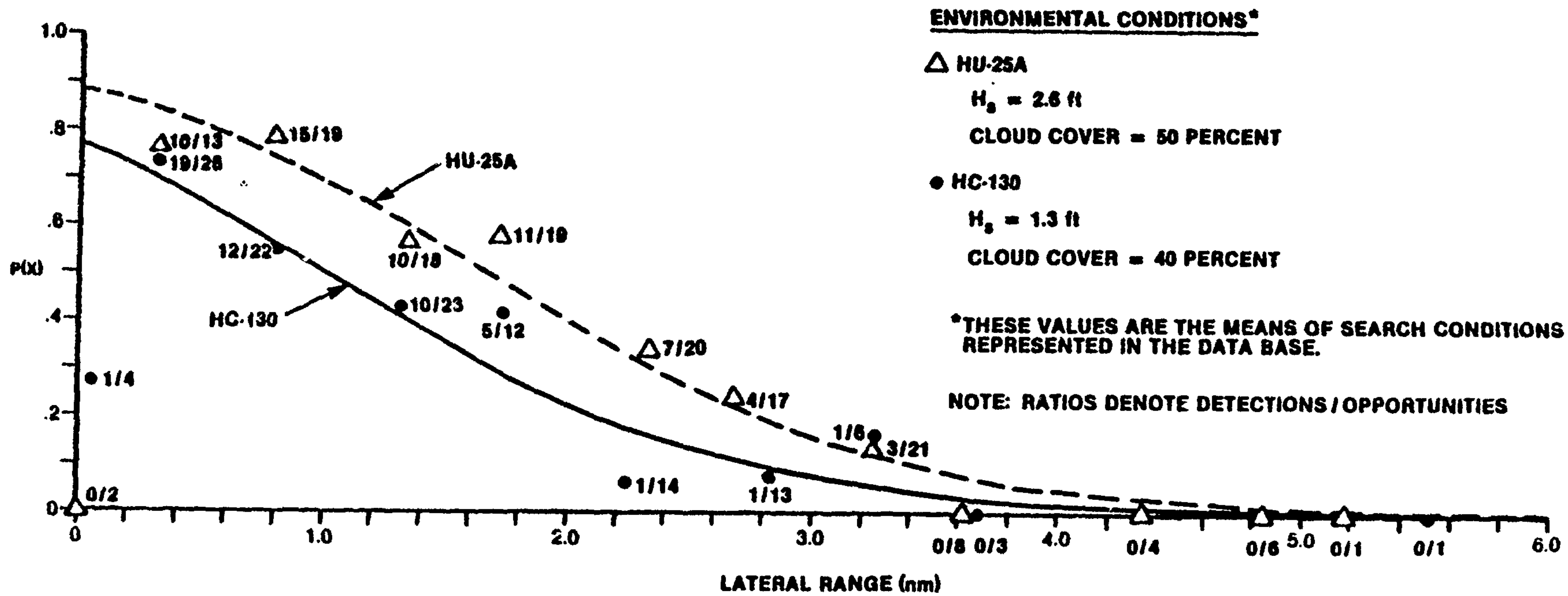


Figure 2-1. Comparison of LOGODDS Model Fit with Raw Data: HU-25A versus HC-130 Aircraft

be compensated for in computer-assisted search planning (CASP) runs (Reference 11) by making slight modifications to LOGODDS-generated lateral range curves in accordance with the empirical data.

Significant wave height and cloud cover both demonstrated the same negative influence on P(x) reported in previous visual detection studies (Reference 5). Figures 2-2 and 2-3 illustrate the influence of these two parameters on the P(x) versus lateral range relationship. In excellent search conditions (0 cloud cover, H_s = 0.5 feet), the model predicts 65- to 97-percent P(x) at lateral ranges under 1 nautical mile, while in relatively poor search conditions (100 percent cloud cover, H_s = 4.0 feet), P(x) values of 16 to 74 percent are predicted. Predicted P(x) drops below 10 percent at 3.3 and 4.5 nautical miles for the HC-130 and HU-25A, respectively, in excellent conditions. In poor conditions, P(x) drops below 10 percent at 1.4 and 2.6 nautical miles, respectively.

Time on task and visibility, while included as variables in the analysis, were not represented by a broad range of values in the data subset analyzed. Most detection opportunities in the data subset occurred with less than 3 hours time on task and visibility greater than 10 nautical miles. Over this limited range of values, time on task and visibility did not make a significant contribution to explaining variability in P(x), even though previous analysis of a more comprehensive fixed-wing aircraft data set had identified them as significant search variables (see Reference 4).

Wind speed, which is usually correlated closely to significant wave height, did not demonstrate a significant influence on P(x) as long as H_s was included in the model. Over the range of conditions represented in the data subset, H_s alone was sufficient input to the model for explaining variability in P(x), even though both wind speed and H_s were found to be significant during the earlier analysis discussed in Reference 5.

Search speed was the variable of primary interest found not to have a significant influence on P(x). Over the range of search speeds that are reasonable for the HU-25A (180 to 240 knots), no significant difference in

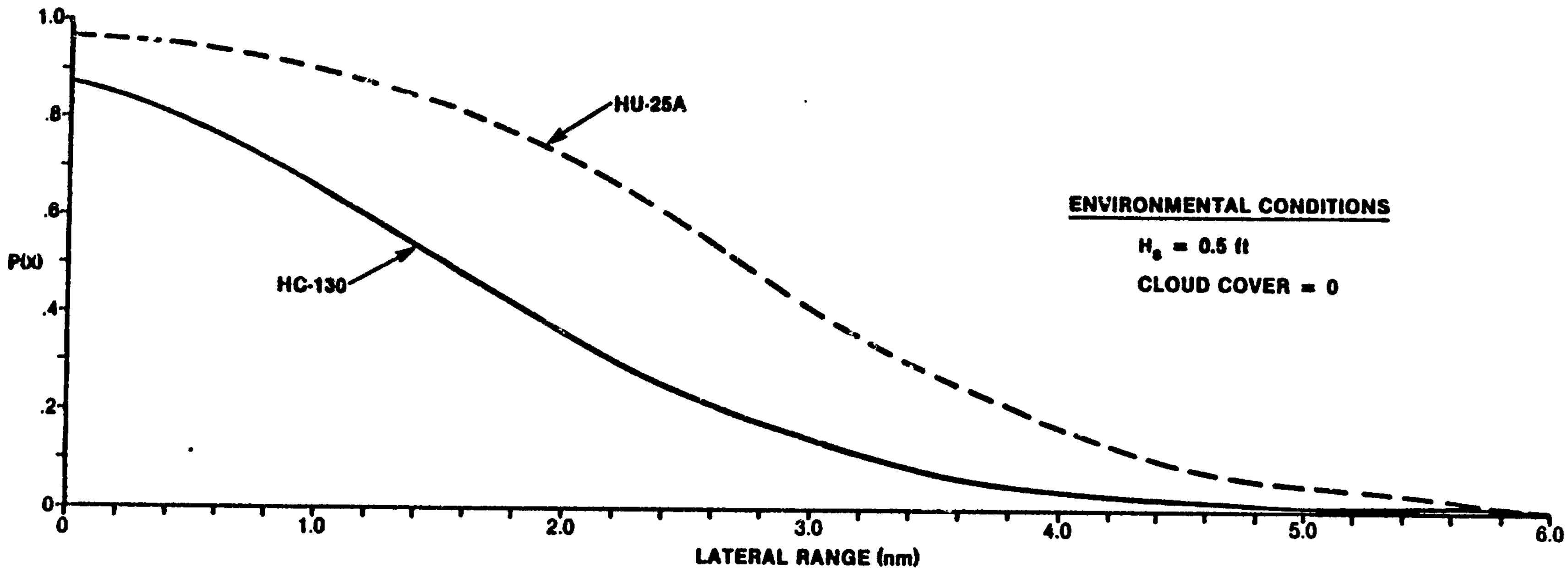


Figure 2-2. Comparison of HU-25A and HC-130 Search Performance in Excellent Conditions

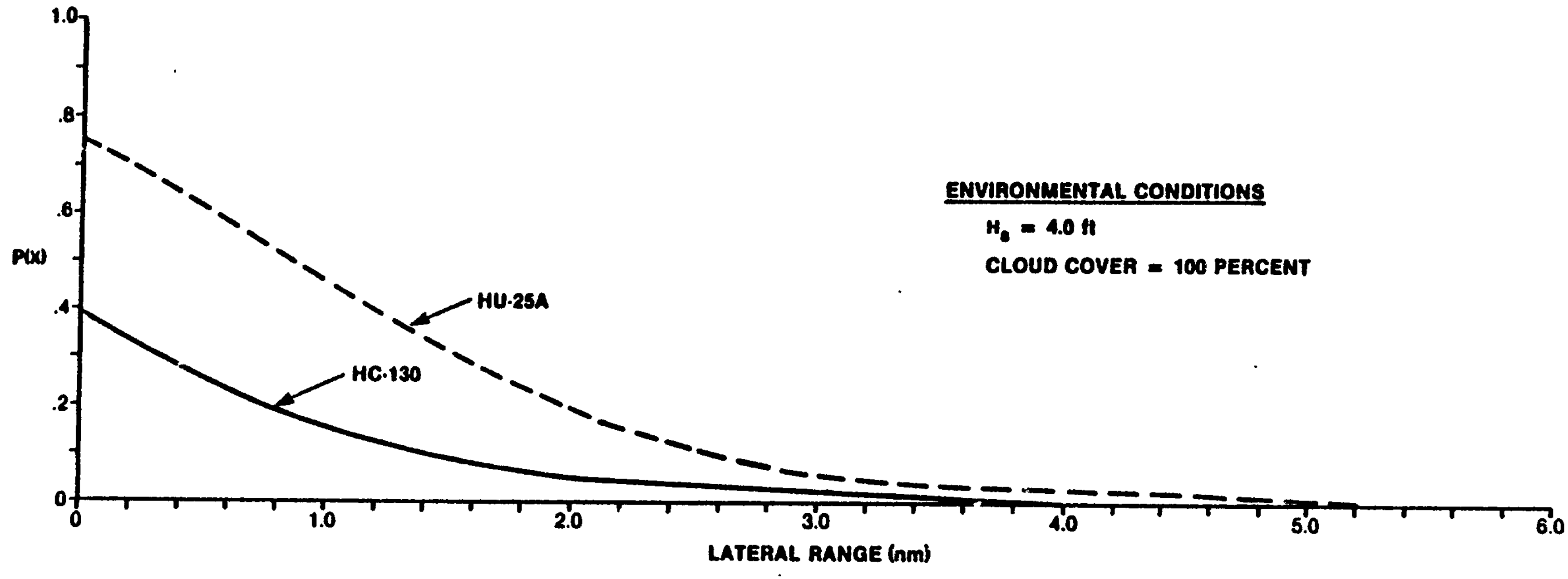


Figure 2-3. Comparison of HU-25A and HC-130 Search Performance in Poor Conditions

target detection probability was identified during the analysis. Figure 2-4 illustrates this lack of strong influence. HU-25A target detection opportunities were sorted into 0.5-nautical mile lateral range bins for the 180- and 240-knot search speeds tested. As Figure 2-4 illustrates, neither search speed is clearly superior to the other at all lateral ranges. The probabilities in Figure 2-4 are somewhat scattered because the number of target detection opportunities in each bin is small, but no biases in H_s or cloud cover (the two significant environmental parameters) exist. The analysis presented in Reference 5, in which search speed <u>was</u> found to be a significant variable, included fixed-wing searches at speeds as low as 120 knots. While large differences in search speed may affect small-target detection performance by fixed-wing aircraft, no <u>statistically significant</u> influence could be identified for the HU-25A over the 180- to 240-knot speed range.

In summary, the HU-25A was found to be a significantly better visual search platform than older Coast Guard fixed-wing aircraft (first analysis objective) and search speeds of 180 to 240 knots were found to result in similar search performance (second analysis objective).

Once the two primary analysis objectives were met, the HU-25A data were combined with all fixed-wing aircraft visual search data collected previously by the POD/SAR Project team. This aggregate data base consisted of all 158 HU-25A target detection opportunities plus 658 detection opportunities obtained during HC-130, HC-131, and HU-16 searches. Analysis of this composite data base indicated that, at the 0.01 level of significance, the following combination of parameters explained variability in P(x):

1. Lateral range,
2. Visibility,
3. Aircraft type,
4. Search speed,
5. Significant wave height,
6. Target type (size, shape, color),
7. Time on task,
8. Wind speed, and
9. Cloud cover.

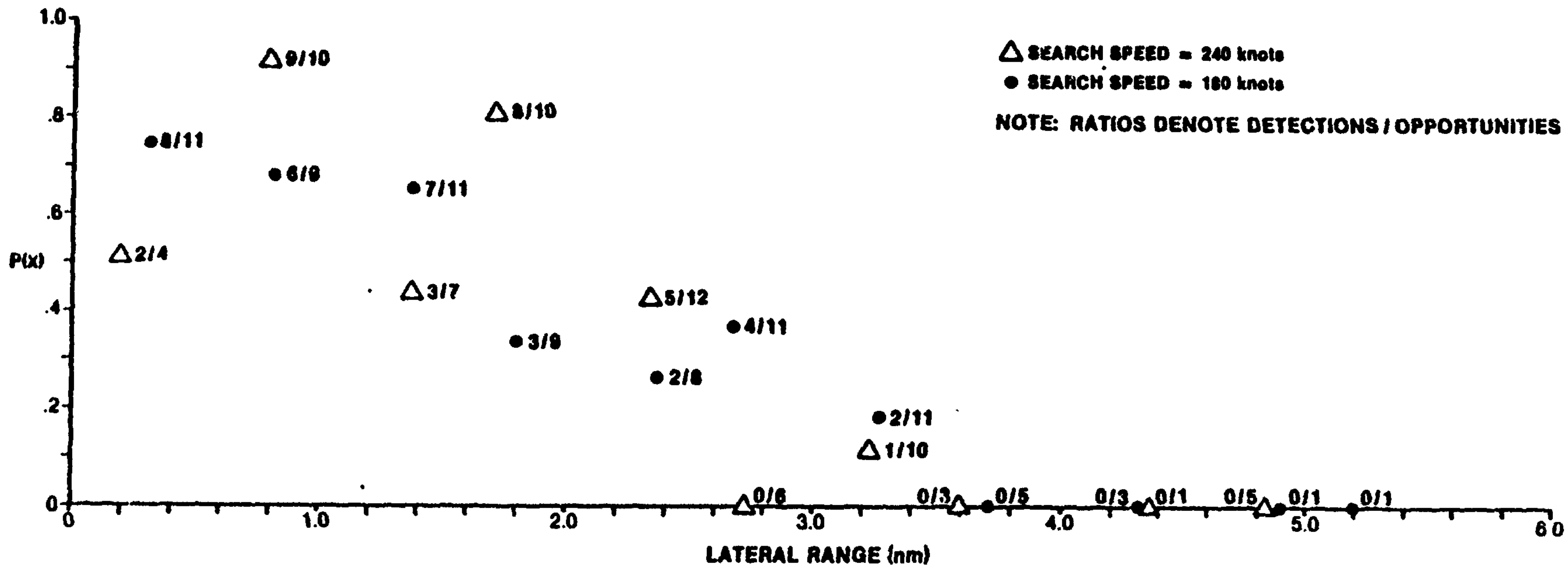


Figure 2-4. Comparison of Raw Search Data: HU-25A at 240 Knots versus 180 Knots

Elevation of the sun and search altitude were not included in the analysis for reasons discussed earlier. Using this larger data set with a greater range of parameter values, the effects of five additional variables were demonstrated to be significant in predicting P(x). This visual detection model incorporates the same variables that were identified in Reference 5 as being significant aircraft visual search performance predictors. While the relative influence of each variable remained essentially unchanged from the older model, the new HU-25A aircraft type added a highly influential parameter to the solution. Whereas the only significant aircraft type differentiation in the older visual detection model was helicopter versus fixed-wing, addition of HU-25A data resulted in a need to differentiate between it and the older fixed-wing aircraft.

The strong influence of aircraft type illustrated by the lateral range curves in Figures 2-1 through 2-3 results in dramatic differences between predicted sweep widths for the HU-25A and other Coast Guard fixed-wing aircraft. Table 2-1 presents sweep width estimates for the same combinations of search parameters used to generate Figures 2-1 through 2-3. Inspection of Table 2-1 indicates that HU-25A sweep width predictions can be more than double those for other fixed-wing aircraft, depending upon search conditions. Attributes of the HU-25A that could be responsible for these superior search performance predictions include:

1. Automated navigation and search pattern execution, which frees the pilots (who are frequently the most experienced scanners onboard the aircraft) to concentrate more on searching,

2. Considerable improvements in crew comfort and reduction of in-flight noise levels, and

3. Improved fields of view for the aft scanners due to large search windows.

Table 2-1. Fixed-Wing Aircraft Sweep Width Comparison (16-foot white boat and orange-canopied life raft targets)

ENVIRONMENTAL CONDITIONS*	BASED UPON 1983 LOGODDS ANALYSIS OF FIXED-WING AIRCRAFT VISUAL DETECTION DATA		BASED UPON 1981 LOGODDS ANALYSIS OF AIRCRAFT VISUAL DETECTION DATA
	HU-25A	HC-130, HC-131, AND HU-16	HC-130, HC-131, AND HU-16
Mean of conditions represented in HC-130 data subset (H_S = 1.3 ft, 40-percent cloud cover, wind speed = 11 knots)	-	2.6	2.8
Mean of conditions represented in HU-25A data subset (H_S = 2.6 ft, 50-percent cloud cover, wind speed = 11 knots)	3.7	-	1.8
Excellent search conditions (H_S = 0.5 ft, 0 cloud cover, wind speed $\leq$8 knots)	5.4	3.4	4.0
Poor search conditions (H_S = 4.0 ft, 100-percent cloud cover, wind speed = 18 knots)	2.1	0.9	0.7

*Assumed values of other significant search parameters are as follows for all four cases:

Visibility = 13 nautical miles

Search Speed = 200 knots

Time on Task = 1 hour

Even when consideration is given to these factors, however, the authors feel that differences in search performance attributed to aircraft type alone may be overstated in the new detection model. Two factors were identified as having potential for biasing the data toward overstating HU-25A search performance relative to other aircraft:

1. Targets used in the HU-25A evaluation were in better condition than those used in previous experiments. The orange life raft canopies were brighter and the white boats were less weather-beaten than those used during most of the HC-130, HC-131, and HU-16 evaluations. These target attributes could have resulted in improved search performance by HU-25A aircrews.

2. The ocean environment in which the HU-25A data were collected differed somewhat from that in which other fixed-wing aircraft were evaluated. The HU-25A was evaluated in an unobstructed coastal zone where ocean swells dominated the wave spectrum. These swells, at 3- to 4-foot amplitudes, do not generate heavy whitecap cover unless there are strong local winds. In contrast, most other fixed-wing aircraft were tested in Block Island Sound off the Connecticut/Rhode Island/New York coast. This is a relatively sheltered area where locally generated wind waves dominate the spectrum. When these waves reach heights of 3 feet or more, moderate to heavy whitecap cover usually results. It is postulated that, because 678 of the 816 total detection opportunities in the composite data base occurred in a wind-wave dominated environment, the visual detection model predicts a stronger detrimental effect on search performance as H_s increases than actually occurred during the Fort Pierce experiment. Since only HU-25A data were collected in this "less H_s-sensitive" area, any resultant improved search performance may have been attributed to the HU-25A aircraft itself instead of to a "softened" H_s influence on search conditions.

The best way either of the above hypotheses could be validated or their effects quantified would be to collect additional HU-25A visual detection data in an area similar to Block Island Sound.

Table 2-1 also includes sweep width estimates from Table 3-7 of Reference 5 for search conditions similar (but not identical) to those listed. Differences between the "old" and "new" sweep width estimates given in Table 2-1 for HC-130, HC-131, and HU-16 aircraft can be accounted for in two ways:

1. The sweep widths taken from Table 3-7 of Reference 5 are averages for a range of search conditions, not the specific conditions listed in Table 2-1, and

2. The sweep widths taken from Reference 5 were generated using a visual detection model that considered both helicopter and fixed-wing aircraft data, whereas the "new" sweep widths were generated using fixed-wing data alone.

Overall, good agreement was found between the "old" and "new" visual detection models for fixed-wing aircraft.

2.2.2 Visual Detection of PIWs

A total of 78 detection opportunities occurred during the two days of PIW searches conducted for the experiment. As Table 1-2 indicates, the environmental conditions were highly unfavorable on both days. Search performance was extremely poor due to the small target size and rough seas; only 4 of the 78 target opportunities were detected. All four detections occurred at lateral ranges of 0.2 nautical mile or less.

These HU-25A data were compared to PIW search data collected using HC-130 and HC-131 aircraft under similar conditions during a 1981 POD/SAR experiment in Panama City, Florida. Search speeds of 150 knots were used by

the HC-130 and HC-131 aircraft; the HU-25A searched at 180 knots. Figure 2-5 illustrates the P(x) versus lateral range relationships for both data sets (only detection opportunities that occurred at lateral ranges of 1 nautical mile or less are shown). As the data in Figure 2-5 demonstrate, fixed-wing aircraft of any type have little hope of detecting PIWs in 3- to 5-foot seas with greater than 10-knot winds. Most detections occur at lateral ranges of 0.1 to 0.2 nautical miles.

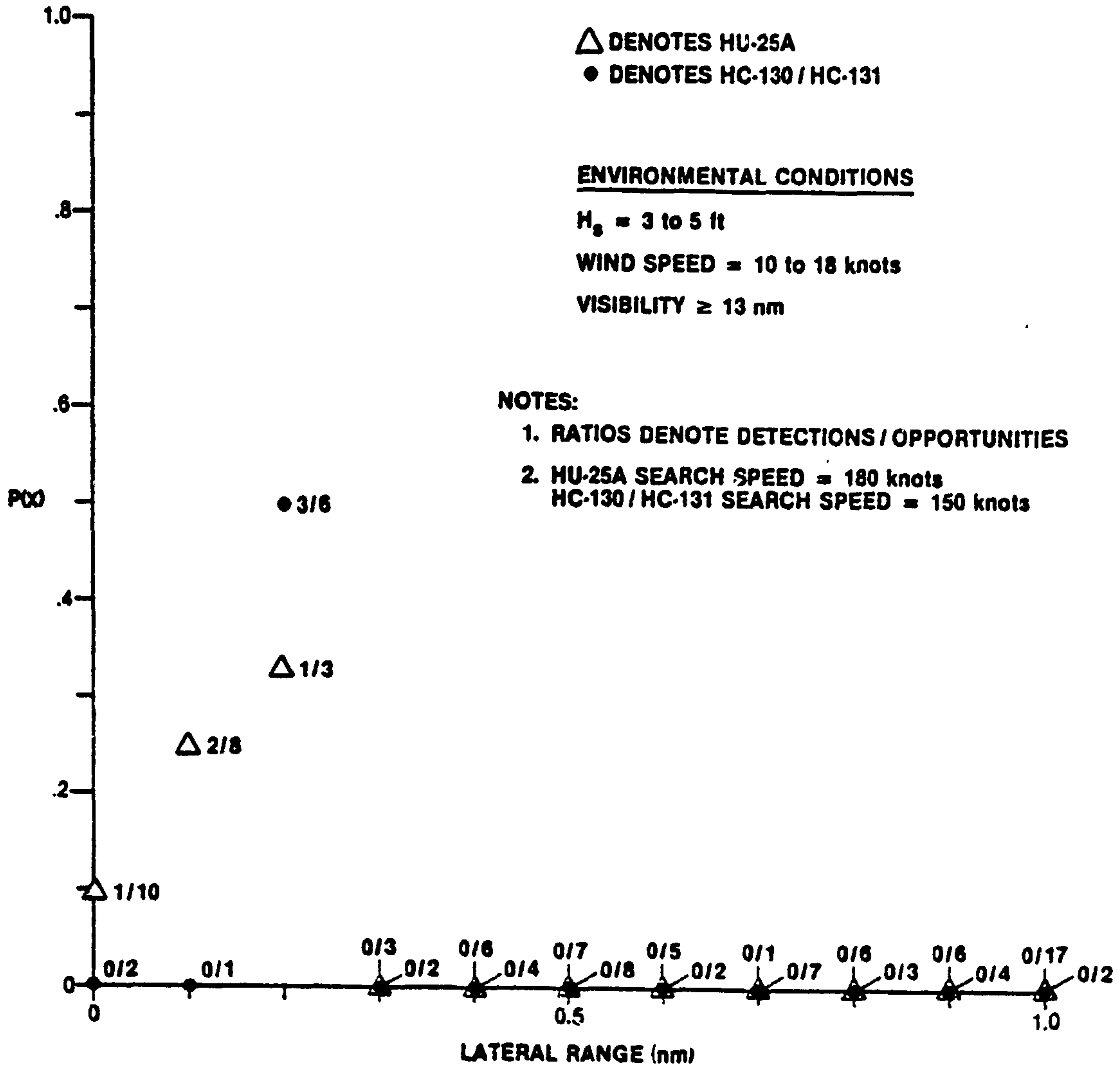


Figure 2-5. Comparison of HU-25A and HC-130/HC-131 Detection Performance: PIW Targets

With the available data, no statistically significant effects of search speed or aircraft type on P(x) could be identified. Sea conditions were clearly the dominant factor in determining PIW search performance with this data set. Additional PIW detection data would have to be collected with the HU-25A under more favorable search conditions before the effects of variables other than H_s and wind speed could be quantified.

2.2.3 HU-25A Detection Envelope

To determine whether the HU-25A provided search crews with a substantially different field of view than other Coast Guard fixed-wing aircraft, small boat and life raft detections were sorted according to the relative bearing of initial sighting. Relative bearing bins 30 degrees wide, centered at each "clock" position, were used for the data sort.

Figure 2-6 depicts the relative frequency of detections that occurred at each bearing with the two categories of aircraft. The data indicate that HU-25A aircrews made 73 percent of their detections between the 10 o'clock and 2 o'clock positions, while HC-130 and HC-131 aircrews made about 59 percent of their detections in the same bearing interval. Virtually all remaining detections were made at the 9 o'clock and 3 o'clock positions in both aircraft categories. Only about 5 percent of all detections were made at the 12 o'clock position, indicating poor field of view at ranges of a few miles or less in the straight-ahead direction for all three aircraft types.

The slight forward bias in HU-25A detections is probably reflective of its low-wing design, large search windows, and adjustable scanner seats which afford the best view and most comfort when looking forward of the beam. No physical reason for the right-left biases of the two data sets was apparent to the authors.

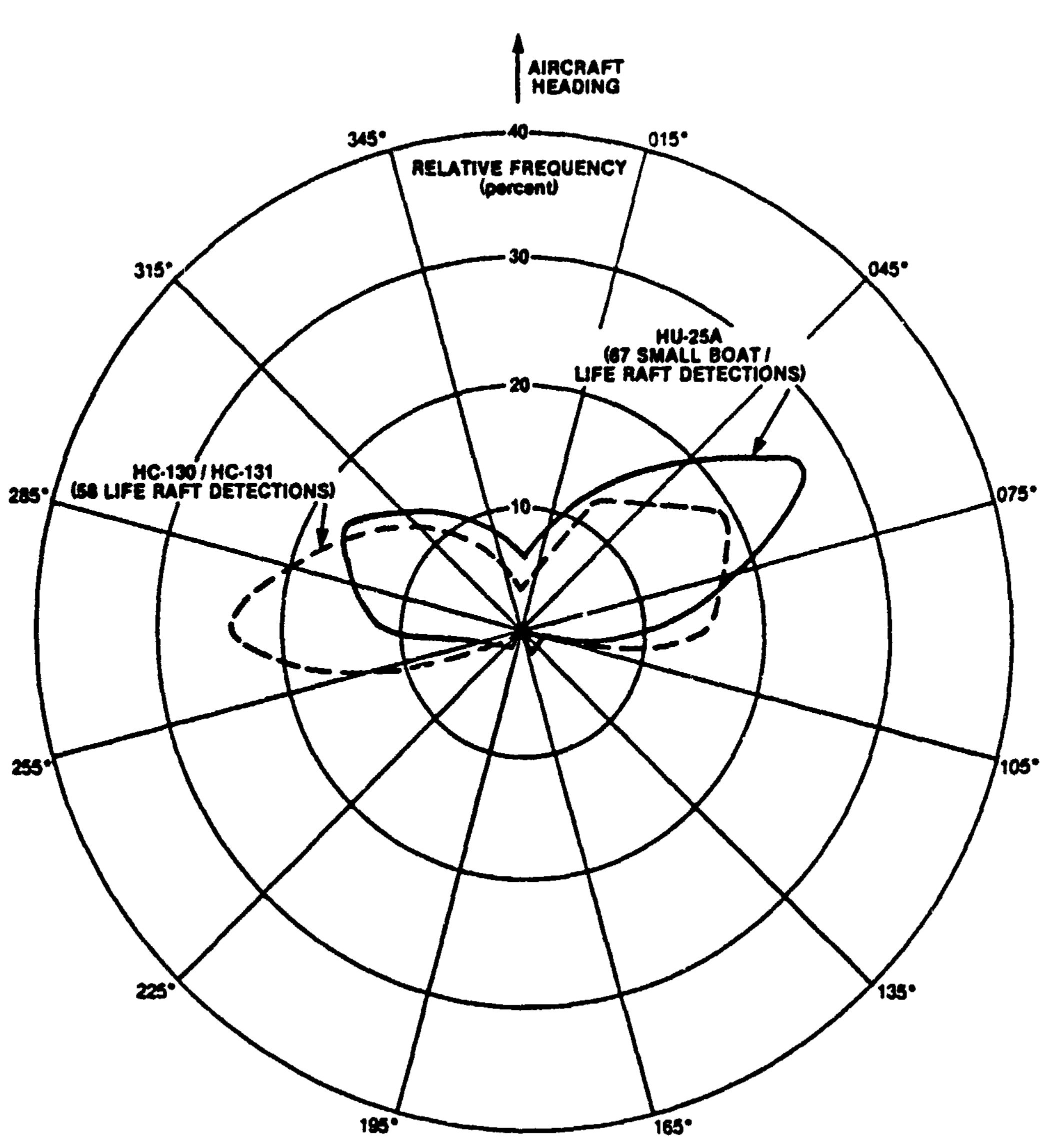


Figure 2-6. Comparison of Detection Envelopes: HU-25A versus HC-130/HC-131

2.3 FLAR DETECTION PERFORMANCE

As stated in Section 1.4.3, the five primary objectives of the FLAR data analysis were to (1) ascertain the CDP-versus-range relationship for FLAR detection of small boats and life rafts, (2) determine the best FLAR search altitude(s) for small targets, (3) determine the influence of H_s on small-

target detection performance, (4) determine the influence of target composition and/or radar reflectors on target detectability, and (5) determine if aircraft orientation relative to major ocean waves and/or surface wind affects FLAR detection performance. CDP curves for logical data groupings were constructed so that a comparison of AN/APS-127 FLAR and AN/SPS-64(V) surface radar detection performance could be made.

Objectives 2 through 5 were addressed initially by sorting the data on parameters of interest and comparing percent of targets detected and mean detection range. Tables 2-2 through 2-5 summarize the results of these data sorts.

Table 2-2 addresses objective (2), the influence of search altitude on FLAR detection performance. The reader will note that only eight target detection opportunities occurred at 1000 feet. This limitation in the data base results from a decision that was made on the first day of FLAR data collection. Since no detections had occurred at 1000 feet on the first search sortie (very heavy sea return was encountered) and previous tests of the AN/APS-127 (Reference 10) had indicated that very low search altitudes were preferable with small targets, it was decided that data collection would be confined to 300- and 500-foot search altitudes. This decision was further prompted by a desire to obtain sufficient data to address all five analysis objectives during the limited search time available. The eight detection opportunities that occurred at 1000 feet were not considered further during data analysis.

Data in Table 2-2 were sorted on significant wave height as well as altitude because these parameters affect sea surface reflectivity and the grazing angle of the radar signal, which, in turn, affect sea return as discussed in References 10 and 12. Analysis of variance at the 0.05 significance level identified no statistically significant differences in either percent of targets detected or detection range between the 300- and 500-foot search altitudes.

Table 2-2. Effects of Search Altitude on FLAR Detection Performance

SIGNIFICANT WAVE HEIGHT (ft)	SEARCH ALTITUDE (ft)	NUMBER OF DETECTION OPPORTUNITIES	NUMBER OF DETECTIONS	PERCENT DETECTED	MEAN DETECTION RANGE (nm)
1.5	300	7	1	14	2.0
	500	19	9	47	1.7
	1000	0	-	-	-
3.5 to 4.5	300	26	4	15	2.4
	500	29	3	10	2.7
	1000	8	0	0	-

Careful inspection of Table 2-2 does indicate a large difference in percent of targets detected in light (1.5-foot) seas between the 300- and 500-foot search altitudes. However, the number of detection opportunities at 300 feet is small (only 7), with the result that the corresponding 14 percent targets-detected statistic is very uncertain and may not indicate any actual difference in detection performance from the 500-foot search altitude. The fact that all seven target opportunities in question occurred on the first FLAR search by an operator who was unfamiliar with small target search methods for the AN/APS-127 further reduces the likelihood that this difference in target detection percentage represents an altitude effect.

Table 2-3 addresses objectives (3) and (4). Analysis of variance indicated that, at the 0.01 significance level, searching in light (1.5-foot) seas resulted in a significantly higher percentage of targets detected than searching in rough (3.5- to 4.5-foot) seas. Overall, 10 of 26 target opportunities (38 percent) were detected in light seas and 7 of 55 opportunities (13 percent) were detected in rough seas. Even if allowance is made for the bias toward targets with radar reflectors in the light sea data by comparing only data for life rafts (see Table 2-3), the percentage of targets detected in light seas is more than twice that for rough seas.

Table 2-3. Effects of Significant Wave Height and Target Type on FLAR Detection Performance

SIGNIFICANT WAVE HEIGHT (ft)	TARGET TYPE	NUMBER OF DETECTION OPPORTUNITIES	NUMBER OF DETECTIONS	PERCENT DETECTED	MEAN DETECTION RANGE (nm)
1.5	16-foot fiber-glass boat without engine or radar reflector	0	-	-	-
	16-foot fiber-glass boat with radar reflector	12	6	50	1.8
	4- to 6-man canopied life raft	14	4	29	1.7
3.5 to 4.5	16-foot fiber-glass boat without engine or radar reflector	22	2	9	2.5
	16-foot fiber-glass boat with radar reflector	2	1	50	2.2
	4- to 6-man canopied life raft	31	4	13	2.6

Mean detection ranges were found to be longer (at the 0.05 significance level) in rough seas than in light seas. This effect can be explained by the fact that, in rough seas, clutter obscures targets that would ordinarily appear on the PPI display at ranges of about 2 nautical miles or less. Thus, while fewer targets are detected by the AN/APS-127 in rough seas, those that are detected can only be distinguished on the PPI display at ranges beyond approximately 2 nautical miles. This is illustrated by the CDP curves in Sec-tion 2.3.1.

Attempts to eliminate heavy sea clutter using the clutter envelope processor (CEP) of the AN/APS-127 resulted in loss of radar contact on targets as large as the 42-foot JENNY D. Based upon this experience, the CEP feature of the AN/APS-127 was not used during data collection and FLAR operators concentrated on the 2- to 5-nautical mile range region of the PPI display when seas were rough.

Table 2-3 also indicates the effect of target type on FLAR detection performance. Analysis of variance at the 0.05 significance level indicated no difference between the percent detected or detection ranges achieved with small fiberglass boats and rubber life rafts when neither was equipped with radar reflectors. This result is best illustrated by comparing the data collected in rough seas. Nine percent of the small fiberglass boats and 13 percent of the life rafts without radar reflectors were detected in these conditions. Detection ranges for both target types averaged about 2.5 nautical miles.

Analysis of variance identified a difference at the 0.01 significance level in percent detected between targets with and without radar reflectors. This difference is best illustrated by comparing the 29-percent life raft detection rate with the 50-percent detection rate for reflector-equipped small boats in light sea conditions. Consistent with surface radar evaluations reported in Reference 9, however, no significant difference in detection ranges achieved with the two target types was demonstrated in the FLAR data.

Table 2-4 summarizes the results of binning only data collected in rough seas according to relative wave direction. While no detections were made searching in the direction of wave propagation, no statistically significant differences in either percent of targets detected or detection range among the three data groups were identified at the 0.05 significance level.

Data presented in Reference 12 indicate that, at wind speeds greater than 5 knots, wind direction, even when different from the direction of dominant ocean wave propagation, is often more closely correlated with sea return than wave height and direction. To examine this hypothesis with the FLAR data, all detection opportunities were sorted according to relative wind direction as shown in Table 2-5. Wind speeds represented in the data range from 6 to 19 knots. Analysis of variance at the 0.05 significance level indicated no difference in the percent-detected statistics among the three data groups. No statistically significant difference in detection ranges between the downwind and crosswind directions was found at the 0.05 significance level, but these two directions were represented by significantly lower (at the 0.05 level) detection ranges than the upwind direction. It is possible that sea clutter on the PPI display was heavier on

Table 2-4. Effects of Relative Wave Direction on FLAR Detection Performance (3.5- to 4.5-foot seas; 6- to 19-knot winds)

RELATIVE WAVE DIRECTION	NUMBER OF DETECTION OPPORTUNITIES	NUMBER OF DETECTIONS	PERCENT DETECTED	MEAN DETECTION RANGE (nm)
Aircraft heading opposite ocean wave direction	11	2	18	2.4
Aircraft heading aligned with ocean wave direction	13	0	0	-
Aircraft heading parallel to wave crests and troughs	31	5	16	2.6

Table 2-5. Effects of Relative Wind Direction on FLAR Detection Performance (1.5- to 4.5-foot seas; 6- to 19-knot winds)

RELATIVE WIND DIRECTION	NUMBER OF DETECTION OPPORTUNITIES	NUMBER OF DETECTIONS	PERCENT DETECTED	MEAN DETECTION RANGE (nm)
Upwind	22	4	17	2.7
Downwind	23	6	26	1.7
Crosswind	36	7	19	2.0

the upwind search legs, resulting in only longer-range detections being made. Upwind clutter has been shown in other studies to be heavier than downwind or crosswind clutter (Reference 12).

The reader is cautioned that wind and sea conditions encountered during the three days of FLAR testing were often very different from each other because the waves were not locally generated. One day, for example, 4- to 6-foot waves were accompanied by only 6- to 9-knot winds, variable in direction. Under such conditions, and with limited data, it is difficult (if not impossible) to distinguish between or to firmly identify the directional effects of either parameter on radar detection performance.

2.3.1 FLAR CDP Curves and Comparison with Surface Radar CDP

Figures 2-7 and 2-8 provide a comparison between CDP curves for the AN/APS-127 searching for canopied life rafts in light (1.5-foot) versus rough (3.5- to 4.5-foot) sea conditions. Figure 2-7 indicates that detections were made in light sea conditions at ranges between 1.3 and 2.1 nautical miles, with a CDP of about 29 percent. Figure 2-8 illustrates the tendency toward longer (1.7- to 3.2-nautical mile) detection ranges in rough seas, with CDP reaching only about 13 percent. Only one detection was made inside 2.5 nautical miles in rough sea conditions, while all four detections made in

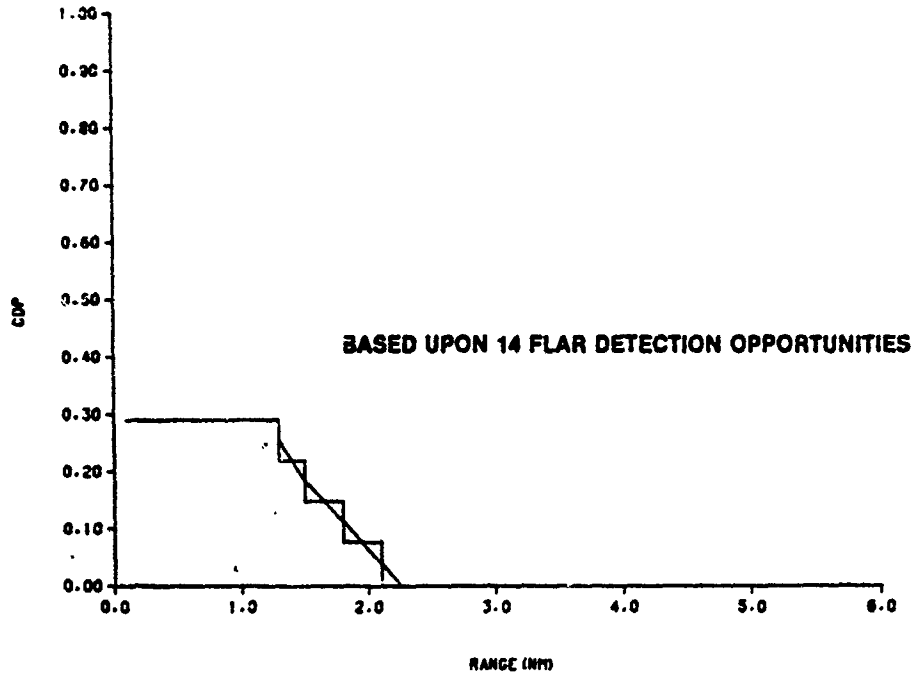


Figure 2-7. CDP versus Range for AN/APS-127 Searching for Canopied Life Rafts Without Radar Reflectors (1.5-foot seas)

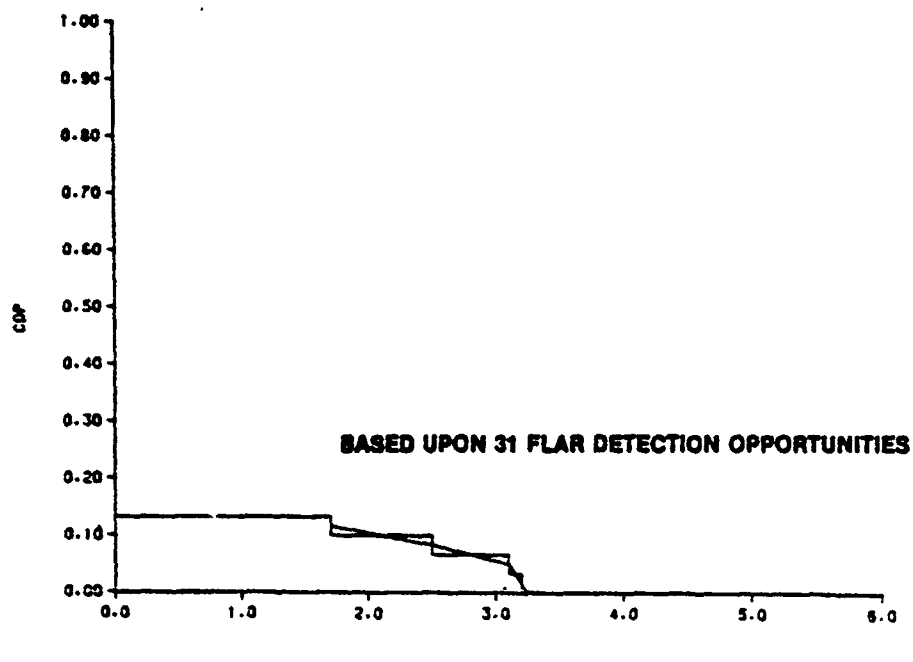


Figure 2-8. CDP versus Range for AN/APS-127 Searching for Canopied Life Rafts Without Radar Reflectors (3.5- to 4.5-foot seas)

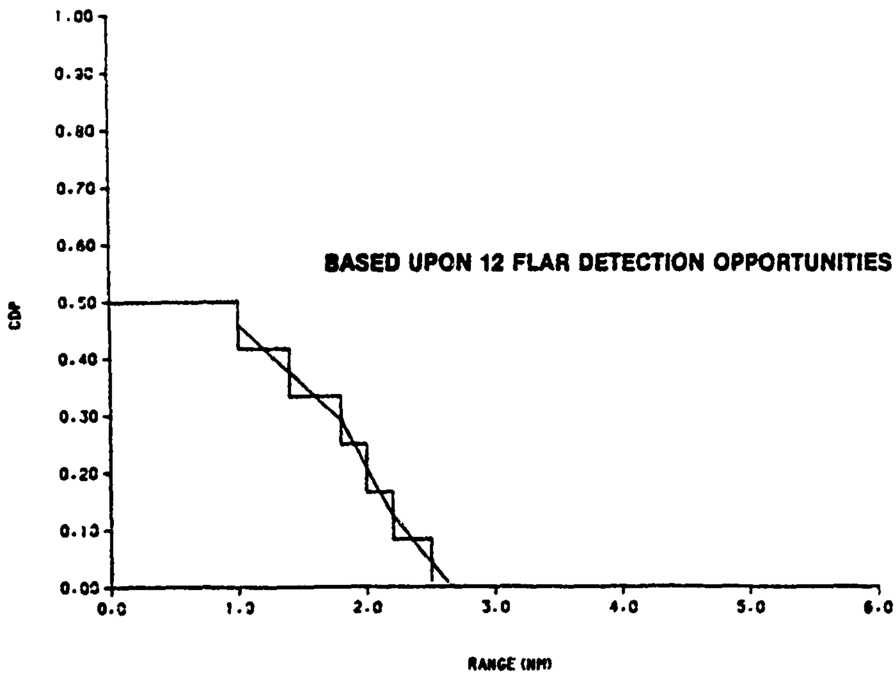


Figure 2-9. CDP versus Range for AN/APS-127 Searching for 16-Foot Boats With Radar Reflectors (1.5-foot seas)

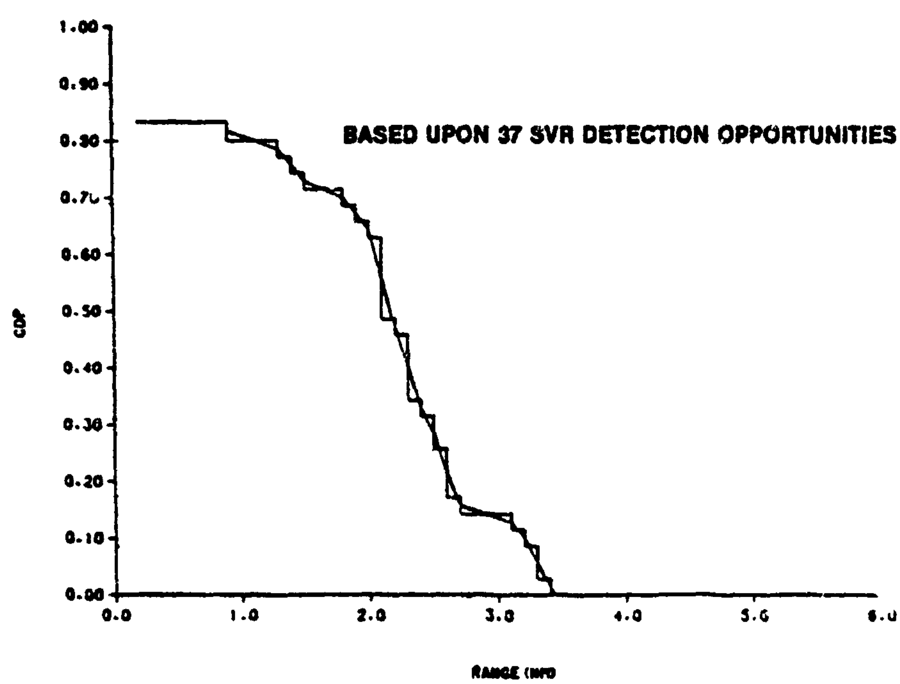


Figure 2-10. CDP versus Range for AN/SPS-64(V) Searching for Small Boats and Life Rafts With Radar Reflectors (0- to 2-foot seas)

light sea conditions occurred inside that range. As stated earlier, the difference in detection ranges with sea conditions probably reflects the size of the sea clutter ring on the PPI display and bias in operator attentiveness to areas just beyond that clutter ring.

Comparison of Figure 2-7 with Figure 2-9 illustrate the improvement in target detectability afforded by using a radar reflector. In light sea conditions, reflector-equipped boats were detected in about the same range interval (1.1 to 2.5 nautical miles) as life rafts without reflectors, but CDP achieved is 50 percent versus 29 percent.

Figure 2-10 is taken from an earlier POD/SAR Project report on surface radar detection performance. Comparing the CDP curves of Figures 2-9 and 2-10 reveals that the AN/SPS-64(V), the Coast Guard's primary surface search radar, detects reflector-equipped small boats and life rafts at about the same ranges as the AN/APS-127 FLAR. The major detection performance difference between the two radars is in CDP achieved. While the AN/SPS-64(V) achieves a CDP of about 83 percent with reflector-equipped targets in light seas, limited data indicate a much lower (50 percent) value for the AN/APS-127. Additional data would be required, however, to firmly conclude that the 50-percent CDP value is representative of AN/APS-127 detection performance under these conditions, since only 12 detection opportunities are represented in Figure 2-9.

Figures 2-11 and 2-12 provide additional evidence that the AN/SPS-64(V) achieves higher CDP than the AN/APS-127. Searching in rough seas for small targets without radar reflectors, the surface radar achieved a CDP of about 22 percent, while the FLAR achieved a CDP of about 11 percent. While neither radar appears to be very effective at detecting small targets without reflectors in rough seas, the CDP curves indicate that the AN/SPS-64(V) may not have been as severely affected by sea clutter as the AN/APS-127. Figure 2-12 indicates that detections were made as close as 0.8 nautical mile to the surface radar, while the minimum FLAR detection range shown in Figure 2-11 is 1.7 nautical miles. The key difference may be that clutter suppression controls on the AN/SPS-64(V) could be used without eliminating small targets, while the CEP feature of the AN/APS-127 could not.

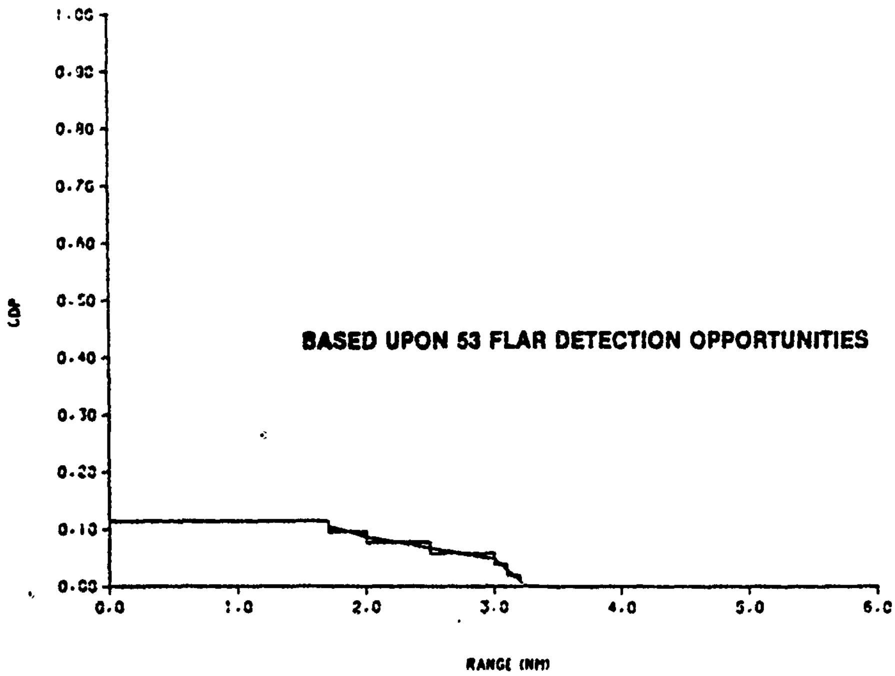


Figure 2-11. CDP versus Range for AN/APS-127 Searching for 16-Foot Boats and Canopied Life Rafts Without Radar Reflectors (3.5- to 4.5-foot seas)

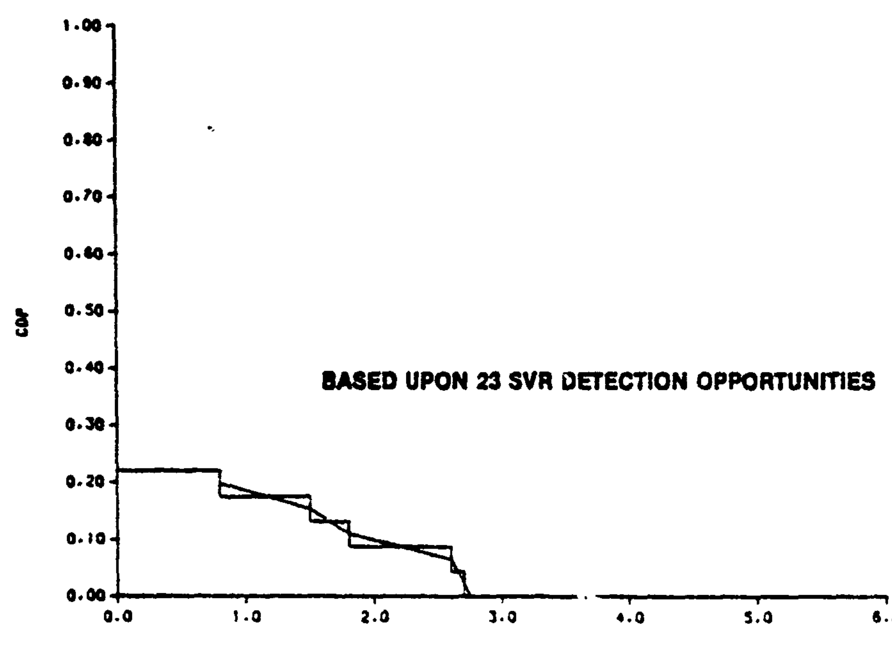


Figure 2-12. CDP versus Range for AN/SPS-64(V) Searching for Small Boats and Life Rafts Without Radar Reflectors (2.5- to 4-foot seas)

Another major reason that the AN/SPS-64(V) apparently achieves higher CDPs than the AN/APS-127 may be a longer target integration time for both the operator and the radar itself. To illustrate this point, assume that both radars achieve virtually all small target detections between 1.5 and 3.5 nautical miles. A Coast Guard cutter cruising at 15 knots toward a small target would take 8 minutes to transit the 2-nautical mile "detection interval," while the HU-25A would take only 40 seconds to transit the same interval even at a "slow" 180-knot search speed. Over this interval, the surface radar operator would have approximately 264 sweeps of the PPI display to study for the target (33 rpm x 8 minutes), while the FLAR operator would have only 80 sweeps (120 rpm x 2/3 minute) to study. Furthermore, the sweep-to-sweep change in relative target position on the PPI would be about three times greater for the FLAR than for the surface radar (given similar range scales), making it more difficult to distinguish targets from sea return. One remedy for the latter problem might be to operate the AN/APS-127 in ground-stabilized mode. However, this mode requires frequent operator attention to the task of repositioning the PPI display origin when using a 5- or 10-nautical mile range scale. This added workload could hinder operator attentiveness to the search task itself, but additional data collection would be required to quantify the detection performance tradeoffs involved.

2.3.2 Comparison with NADC Field Test Data

In 1976 and 1977, the Naval Air Development Center (NADC) conducted flight and shore-based evaluations of an AN/APS-127 prototype. While the NADC tests differed from this experiment in the targets and data collection procedures used, some approximate comparisons between the two data sets can be made. Major differences between the two data sets are as follows:

1. The smallest target used in the NADC tests was an 18-foot fiberglass Coast Guard boat with inboard/outboard engine. Targets used during this experiment that were closest to this in radar cross section were probably the reflector-equipped fiberglass boats.

2. During the NADC tests, the prototype radar was maintained in top operating condition and monitored constantly for degradation. The AN/APS-127 used during this experiment received no special care or maintenance.

3. It is likely that expert advice was available to the FLAR operators concerning proper gain, brightness, and persistence control adjustments during the NADC tests. Expert advice was not available to the operators during this experiment.

4. NADC flight test data were collected in a different manner than the data presented in the report. NADC flights were conducted as tracking runs, from which contact-held percentage as a function of range was computed instead of CDP.

Detection performance during the NADC tests was notably better than that achieved during this experiment.

Data presented in the NADC report (Reference 10) indicate that an 18-foot Coast Guard boat was detected consistently at ranges of 2 to 10 nautical miles from a 500-foot search altitude in 2- to 3-foot seas and 14- to 16-knot winds. As Figure 2-11 of this report demonstrates, initial target detections did not occur at ranges beyond 3.2 nautical miles during this experiment. When conditions deteriorate to 4- to 6-foot seas and 25-knot winds, the NADC report concludes, "...while performance at 500 feet is best, it is well below useful detection levels," and "A target of this size is not detectable by the APS-127 in a sea state 3." This conclusion is certainly consistent with data collected in only slightly better conditions during this experiment.

During the NADC tests, data were collected at altitudes of 500, 1000, and 1500 feet. The report concludes that 500-foot or lower search altitudes are clearly preferred with the AN/APS-127, especially when searching for small targets. Sea clutter was observed to increase substantially at altitudes of 1000 feet and above. While only eight detection opportunities (on one search sortie) occurred at 1000 feet during this experiment, similar sea clutter response was observed.

CHAPTER 3
CONCLUSIONS AND RECOMMENDATIONS

3.1 CONCLUSIONS

3.1.1 Conclusions Regarding HU-25A Visual Search Performance

The following conclusions are drawn based upon analysis of the HU-25A visual search data:

1. The effects of environmental and aircraft-related search variables demonstrated in the HU-25A visual search data collected during this experiment were consistent with the aircraft visual detection model presented in Reference 5.

2. With 16-foot white boat and orange-canopied life raft targets, the HU-25A achieves visual detection performance superior to that of previously tested Coast Guard fixed-wing aircraft (HC-130, HC-131, and HU-16). Further data collection in an environment similar to Block Island Sound would be required to precisely quantify the magnitude of this improvement.

3. No significant variation in HU-25A visual detection performance results from searching at speeds between 180 and 240 knots for 16-foot white boat and orange-canopied life raft targets.

4. In 3.5- to 4.5-foot seas, the HU-25A achieves no better PIW detection performance than HC-130 and HC-131 aircraft. Under these conditions, PIW detection probabilities of less than 50 percent can be expected at lateral ranges under 0.2 nautical miles with virtually no chance of detection at greater lateral ranges.

3.1.2 Conclusions Regarding AN/APS-127 FLAR Detection Performance

1. The detection performance of the AN/APS-127 FLAR is better at altitudes of 500 feet or below than at the 1000-foot level. Searching at 1000 feet appears to increase sea return and degrade detection performance. No statistically significant differences in detection performance between AN/APS-127 FLAR searches for small (<20-foot) targets conducted at altitudes of 300 and 500 feet could be identified from the limited data collected. This conclusion should be substantiated by the collection of additional data.

2. The AN/APS-127 achieves significantly better small-target CDP in light (~1.5-foot) seas than it does in rough (~3.5- to 4.5-foot) seas.

3. Fiberglass boats under 20 feet long without radar reflectors and 4- to 6-man rubber life rafts can be treated as similar FLAR targets by search planners. Use of a radar reflector on small boats significantly improves CDP but does not appear to increase maximum detection range significantly.

4. Relative ocean wave direction and relative wind direction do not appear to demonstrate any clear influence on FLAR detection performance. Detection ranges appear to be slightly longer when searching upwind, probably due to a larger sea clutter ring on the PPI display.

5. On the basis of subjective observations, it appears that FLAR detection performance might have been better if operators had been trained in methods for optimizing AN/APS-127 display effectiveness on small target searches. Performance achieved during this experiment is representative of that obtainable with present operator training and experience levels.

6. While FLAR detection performance is sensitive to the amount of sea clutter on the PPI display, use of the CEP on the AN/APS-127 results in elimination of small-target echoes. The CEP does not appear to be suitable for use on small-target searches.

3.2 RECOMMENDATIONS

3.2.1 Recommendations Concerning HU-25A Visual Search

1. As a conservative estimate of HU-25A visual search performance, search planners should use existing fixed-wing aircraft sweep width estimates as promulgated in Reference 5 and/or the upcoming revision to Chapter 8 of Reference 3.

2. The visual detection model for fixed-wing aircraft promulgated in Reference 5 should be modified to reflect the improved visual detection performance of the HU-25A once data required to precisely quantify this factor are collected.

3. During HU-25A searches for small boats, life rafts, or larger targets, speeds up to 240 knots should be selected on the basis of operational considerations such as aircraft range or fuel economy rather than detection performance.

4. When multiple searches of an area are conducted, search planners should offset fixed-wing aircraft search tracks approximately 0.2 nautical mile to compensate for a probable null area in scanners' field of view due to obstruction by the fuselage.

3.2.2 Recommendations Concerning HU-25A FLAR Search

1. FLAR searches for small boats and life rafts should be conducted at altitudes of 500 feet or less.

2. The 5-nautical mile range scale of the AN/APS-127 should be used during small target searches to provide the best possible range resolution and fewest extraneous contacts on the PPI display.

3. The CEP feature of the AN/APS-127 should not be used during searches for small (<20-foot) boats and life rafts unless the FLAR operator can obtain visual confirmation while enroute to the search area that its use is not eliminating similar targets.

4. Training in AN/APS-127 small-target search techniques should be provided to all FLAR operators.

3.2.3 Recommendations for Future Research

1. Additional HU-25A visual detection data should be collected (using small boat and life raft targets) in a wind wave-dominated environment such as Block Island Sound. These data should be used to quantify more precisely the improvement in visual detection performance achievable with the HU-25A relative to other Coast Guard fixed-wing aircraft.

2. HU-25A visual detection data should be collected in light (<2-foot) sea conditions with PIW targets to provide a meaningful basis for comparing HU-25A PIW detection performance with that of other Coast Guard aircraft.

3. If additional visual detection data are collected using fixed-wing aircraft, some targets should be placed within 0.1 nautical mile of the intended search track. This would provide data to better quantify any degradation in P(x) due to fuselage obstruction of scanners' fields of view.

4. Future FLAR evaluations should be conducted using operators with specific training in small-target search techniques, or, as a minimum, using highly specific instructions as to PPI display set-up requirements.

5. During future evaluations, the FLAR system should be checked daily to ensure it is operating within specifications.

6. Small-target detection data should be collected using the AN/APS-127 in ground-stabilized mode to determine if it improves detection performance in spite of increased operator workload.

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APPENDIX A
VISUAL SEARCH RAW DATA

This appendix contains raw data files for the daily visual search exercises by individual target type. LOGODDS computer runs were made using aggregates of these files. The following is a key to the format of the visual search raw data files:

Column 1:	Detection (1 = yes, 0 = no)
Column 2:	Lateral range (nautical miles)
Column 3:	Time on task (hours)
Column 4:	Meteorological visibility (nautical miles)
Column 5:	Wind speed (knots)
Column 6:	Cloud cover (1/10ths)
Column 7:	Significant wave height (feet)
Column 8:	Search speed (knots)
Column 9:	Altitude (feet)
Column 10:	Elevation of sun (degrees)
Column 11:	Target type (see below; not used for PIW searches)

VISUAL TARGET TYPES

-1 - indicates 16-foot white boat

2 - indicates 4- to 6-man orange-canopied life raft

HU-25A   8 FEB 83   LIFERAFTS

1	0.50	0.20	15.00	12.50	0.80	4.00	180.00	1000.00	42.00	2.00
1	0.80	1.10	15.00	12.50	0.80	4.00	180.00	1000.00	47.00	2.00
0	3.40	0.50	15.00	12.50	0.80	4.00	180.00	1000.00	43.00	2.00
0	3.20	0.80	15.00	12.50	0.80	4.00	180.00	1000.00	46.00	2.00
1	0.20	1.30	15.00	12.50	0.50	3.50	180.00	1000.00	38.00	2.00
0	3.90	1.40	15.00	12.50	0.50	3.50	180.00	1000.00	37.00	2.00
0	3.70	2.20	15.00	12.50	0.50	3.50	180.00	1000.00	29.00	2.00
0	0.30	2.40	15.00	12.50	0.50	3.50	180.00	1000.00	27.00	2.00

HU-25A   8 FEB 83   16 FT. BOATS

1	0.40	0.10	15.00	12.50	0.80	4.00	180.00	1000.00	41.00	-1.00
1	0.60	0.80	15.00	12.50	0.80	4.00	180.00	1000.00	46.00	-1.00
1	0.20	1.10	15.00	12.50	0.80	4.00	180.00	1000.00	47.00	-1.00
1	2.60	1.50	15.00	12.50	0.50	3.50	180.00	1000.00	37.00	-1.00
1	1.20	2.10	15.00	12.50	0.50	3.50	180.00	1000.00	30.00	-1.00
1	2.80	2.20	15.00	12.50	0.50	3.50	180.00	1000.00	29.00	-1.00
0	3.20	0.20	15.00	12.50	0.80	4.00	180.00	1000.00	40.00	-1.00
0	0.80	0.40	15.00	12.50	0.80	4.00	180.00	1000.00	43.00	-1.00
0	4.20	1.00	15.00	12.50	0.80	4.00	180.00	1000.00	47.00	-1.00
0	3.40	1.00	15.00	12.50	0.80	4.00	180.00	1000.00	47.00	-1.00
0	1.50	1.60	15.00	12.50	0.50	3.50	180.00	1000.00	35.00	-1.00

HU-25A	9 FEB 83		LIFERAFTS							
1	2.40	0.30	12.00	12.00	0.30	3.50	180.00	1000.00	43.00	2.00
1	0.60	0.40	12.00	12.00	0.30	3.50	180.00	1000.00	43.00	2.00
1	0.20	0.40	12.00	12.00	0.30	3.50	180.00	1000.00	44.00	2.00
1	0.50	0.80	12.00	12.00	0.30	3.50	240.00	1000.00	46.00	2.00
1	0.90	0.80	12.00	12.00	0.30	3.50	240.00	1000.00	46.00	2.00
1	0.30	1.80	12.00	8.00	0.20	3.00	240.00	1000.00	37.00	2.00
0	1.60	0.20	12.00	12.00	0.30	3.50	180.00	1000.00	43.00	2.00
0	3.30	0.30	12.00	12.00	0.30	3.50	180.00	1000.00	43.00	2.00
0	2.40	0.90	12.00	12.00	0.30	3.50	240.00	1000.00	46.00	2.00
0	3.30	0.90	12.00	12.00	0.30	3.50	240.00	1000.00	46.00	2.00
0	3.60	0.90	12.00	12.00	0.30	3.50	240.00	1000.00	47.00	2.00
0	1.60	1.10	12.00	12.00	0.30	3.50	240.00	1000.00	47.00	2.00
0	1.70	1.10	12.00	8.00	0.20	3.00	180.00	1000.00	44.00	2.00
0	3.60	1.30	12.00	8.00	0.20	3.00	180.00	1000.00	43.00	2.00
0	2.40	1.30	12.00	8.00	0.20	3.00	180.00	1000.00	42.00	2.00
0	0.30	1.50	12.00	8.00	0.20	3.00	180.00	1000.00	41.00	2.00
0	2.30	2.00	12.00	8.00	0.20	3.00	240.00	1000.00	36.00	2.00
0	1.50	2.10	12.00	8.00	0.20	3.00	240.00	1000.00	35.00	2.00
0	3.60	2.00	12.00	8.00	0.20	3.00	240.00	1000.00	36.00	2.00

HU-25A	9 FEB 83		16 FT. BOATS							
1	1.00	1.20	12.00	8.00	0.20	3.00	180.00	1000.00	43.00	-1.00
1	1.30	1.20	12.00	8.00	0.20	3.00	180.00	1000.00	43.00	-1.00
1	0.80	2.10	12.00	6.00	0.20	3.00	240.00	1000.00	35.00	-1.00
0	1.60	0.10	12.00	12.00	0.30	3.50	180.00	1000.00	42.00	-1.00
0	2.50	0.20	12.00	12.00	0.30	3.50	180.00	1000.00	42.00	-1.00
0	1.40	0.20	12.00	12.00	0.30	3.50	180.00	1000.00	42.00	-1.00
0	2.60	0.40	12.00	12.00	0.30	3.50	180.00	1000.00	44.00	-1.00
0	2.80	0.80	12.00	12.00	0.30	3.50	240.00	1000.00	46.00	-1.00
0	1.30	0.90	12.00	12.00	0.30	3.50	240.00	1000.00	47.00	-1.00
0	2.60	0.90	12.00	12.00	0.30	3.50	240.00	1000.00	47.00	-1.00
0	1.40	1.00	12.00	12.00	0.30	3.50	240.00	1000.00	47.00	-1.00
0	3.10	1.30	12.00	8.00	0.20	3.00	180.00	1000.00	43.00	-1.00
0	2.60	1.50	12.00	8.00	0.20	3.00	180.00	1000.00	41.00	-1.00
0	2.70	1.80	12.00	8.00	0.20	3.00	240.00	1000.00	37.00	-1.00
0	3.20	2.00	12.00	8.00	0.20	3.00	240.00	1000.00	36.00	-1.00

HH-25A	11 FEB 83		LIFERAFTS							
1	0.60	0.90	15.00	0.00	0.10	1.00	240.00	1000.00	43.00	2.00
1	2.20	1.00	15.00	0.00	0.10	1.00	240.00	1000.00	43.00	2.00
1	1.70	1.00	15.00	0.00	0.10	1.00	240.00	1000.00	43.00	2.00
1	1.90	1.20	15.00	0.00	0.10	1.00	240.00	1000.00	44.00	2.00
1	2.00	0.30	15.00	0.00	0.10	1.00	180.00	1000.00	37.00	2.00
1	0.30	0.40	15.00	0.00	0.10	1.00	180.00	1000.00	38.00	2.00
0	2.00	0.10	15.00	0.00	0.10	1.00	180.00	1000.00	35.00	2.00
0	2.50	0.10	15.00	0.00	0.10	1.00	180.00	1000.00	35.00	2.00
0	1.60	0.30	15.00	0.00	0.10	1.00	180.00	1000.00	37.00	2.00
0	4.40	0.70	15.00	0.00	0.10	1.00	240.00	1000.00	42.00	2.00
0	3.60	1.00	15.00	0.00	0.10	1.00	240.00	1000.00	43.00	2.00
0	2.20	1.20	15.00	0.00	0.10	1.00	240.00	1000.00	45.00	2.00
0	4.50	0.70	15.00	0.00	0.10	1.00	180.00	1000.00	40.00	2.00
0	3.70	0.30	15.00	0.00	0.10	1.00	180.00	1000.00	37.00	2.00

HH-25A	11 FEB 83		16 FT. BOATS							
1	3.20	0.80	15.00	0.00	0.10	1.00	240.00	1000.00	42.00	-1.00
1	0.70	0.90	15.00	0.00	0.10	1.00	240.00	1000.00	43.00	-1.00
1	0.90	0.50	15.00	0.00	0.10	1.00	180.00	1000.00	39.00	-1.00
1	3.20	0.60	15.00	0.00	0.10	1.00	180.00	1000.00	40.00	-1.00
0	4.80	1.00	15.00	0.00	0.10	1.00	240.00	1000.00	43.00	-1.00

HB-25A 17 FEB 83 LIFERAFTS

1	0.90	0.30	12.00	16.00	0.70	3.50	180.00	1500.00	50.00	2.00
1	1.40	0.40	12.00	16.00	0.70	3.50	180.00	1500.00	50.00	2.00
1	2.70	0.50	12.00	16.00	0.70	3.50	180.00	1500.00	50.00	2.00
1	1.20	0.80	12.00	16.00	0.70	3.50	240.00	1500.00	50.00	2.00
1	0.80	0.90	12.00	16.00	0.70	3.50	240.00	1500.00	50.00	2.00
1	0.80	1.00	12.00	16.00	0.70	3.50	240.00	1500.00	49.00	2.00
1	3.50	1.20	12.00	16.00	0.50	3.50	180.00	1500.00	37.00	2.00
1	0.40	1.30	12.00	16.00	0.50	3.50	180.00	1500.00	36.00	2.00
1	1.10	1.40	12.00	16.00	0.50	3.50	180.00	1500.00	36.00	2.00
1	1.70	1.50	12.00	16.00	0.50	3.50	180.00	1500.00	34.00	2.00
1	1.50	1.90	15.00	8.00	0.30	1.50	240.00	1500.00	29.00	2.00
1	1.00	2.00	15.00	8.00	0.30	1.50	240.00	1500.00	27.00	2.00
1	0.70	2.00	15.00	8.00	0.30	1.50	240.00	1500.00	27.00	2.00
0	4.90	0.00	12.00	16.00	0.70	3.50	180.00	1500.00	50.00	2.00
0	3.20	0.40	12.00	16.00	0.70	3.50	180.00	1500.00	50.00	2.00
0	2.60	0.70	12.00	16.00	0.70	3.50	240.00	1500.00	50.00	2.00
0	4.90	0.80	12.00	16.00	0.70	3.50	240.00	1500.00	50.00	2.00
0	3.10	0.60	12.00	16.00	0.70	3.50	240.00	1500.00	50.00	2.00
0	3.20	1.00	12.00	16.00	0.70	3.50	240.00	1500.00	49.00	2.00
0	4.90	1.10	12.00	16.00	0.70	3.50	240.00	1500.00	49.00	2.00
0	5.20	1.10	12.00	16.00	0.50	3.50	180.00	1500.00	37.00	2.00
0	3.00	1.50	12.00	16.00	0.50	3.50	180.00	1500.00	35.00	2.00
0	2.30	1.60	12.00	16.00	0.50	3.50	180.00	1500.00	32.00	2.00
0	4.40	1.50	12.00	16.00	0.50	3.50	180.00	1500.00	34.00	2.00
0	5.00	2.10	15.00	8.00	0.30	1.50	240.00	1500.00	27.00	2.00
0	3.20	1.90	15.00	8.00	0.30	1.50	240.00	1500.00	29.00	2.00
0	2.50	1.80	15.00	8.00	0.30	1.50	240.00	1500.00	30.00	2.00
0	4.60	1.90	15.00	8.00	0.30	1.50	240.00	1500.00	29.00	2.00
0	3.30	2.10	15.00	8.00	0.30	1.50	240.00	1500.00	27.00	2.00

HU-25A 17 FEB 83 16 FT. BOATS

1	1.60	0.10	12.00	16.00	0.70	3.50	180.00	1500.00	50.00	-1.00
1	1.60	1.10	12.00	16.00	0.70	3.50	240.00	1500.00	49.00	-1.00
1	2.60	1.30	12.00	16.00	0.50	3.50	180.00	1500.00	36.00	-1.00
1	2.20	1.30	12.00	16.00	0.50	3.50	180.00	1500.00	36.00	-1.00
1	1.70	1.90	15.00	8.00	0.30	1.50	240.00	1500.00	30.00	-1.00
1	2.40	2.00	15.00	8.00	0.30	1.50	240.00	1500.00	28.00	-1.00
1	2.30	2.00	15.00	8.00	0.30	1.50	240.00	1500.00	28.00	-1.00
1	1.70	2.10	15.00	8.00	0.30	1.50	240.00	1500.00	26.00	-1.00
0	2.40	0.20	12.00	16.00	0.70	3.50	180.00	1500.00	50.00	-1.00
0	1.90	0.80	12.00	16.00	0.70	3.50	240.00	1500.00	50.00	-1.00
0	2.20	0.90	12.00	16.00	0.70	3.50	240.00	1500.00	49.00	-1.00
0	2.50	0.90	12.00	16.00	0.70	3.50	240.00	1500.00	50.00	-1.00
0	1.80	1.20	12.00	16.00	0.50	1.50	180.00	1500.00	37.00	-1.00
0	1.40	1.50	12.00	16.00	0.50	1.50	180.00	1500.00	34.00	-1.00

HU-25A 18 FEB 83 PIW

0	1.00	0.00	15.00	18.00	0.00	4.00	180.00	500.00	37.00
0	0.00	0.60	15.00	18.00	0.00	4.00	180.00	500.00	30.00
0	1.00	0.20	15.00	18.00	0.00	4.00	180.00	500.00	36.00
0	0.00	0.50	15.00	18.00	0.00	4.00	180.00	500.00	32.00
0	0.40	0.30	15.00	18.00	0.00	4.00	180.00	500.00	35.00
0	0.50	0.40	15.00	18.00	0.00	4.00	180.00	500.00	33.00
0	0.60	0.30	15.00	18.00	0.00	4.00	180.00	500.00	35.00
0	0.50	0.60	15.00	18.00	0.00	4.00	180.00	500.00	32.00
0	0.30	0.20	15.00	18.00	0.00	4.00	180.00	500.00	36.00
0	0.80	0.60	15.00	18.00	0.00	4.00	180.00	500.00	31.00
0	0.80	0.70	15.00	18.00	0.00	4.00	240.00	500.00	29.00
0	1.00	0.80	15.00	18.00	0.00	4.00	240.00	500.00	28.00
0	0.10	1.10	15.00	14.50	0.40	4.00	240.00	500.00	25.00
0	0.40	0.90	15.00	18.00	0.00	4.00	240.00	500.00	27.00
0	0.50	1.00	15.00	14.50	0.40	4.00	240.00	500.00	26.00
0	0.70	0.90	15.00	18.00	0.00	4.00	240.00	500.00	27.00
0	0.40	1.10	15.00	14.50	0.40	4.00	240.00	500.00	25.00
0	0.30	0.80	15.00	18.00	0.00	4.00	240.00	500.00	28.00
0	0.80	1.20	15.00	14.50	0.40	4.00	240.00	500.00	24.00
0	1.00	1.50	15.00	14.50	0.40	4.00	180.00	500.00	20.00
0	0.10	1.70	15.00	14.50	0.50	4.00	180.00	500.00	17.00
0	0.40	1.50	15.00	14.50	0.40	4.00	180.00	500.00	20.00
0	0.50	1.60	15.00	14.50	0.40	4.00	180.00	500.00	18.00
0	0.60	1.50	15.00	14.50	0.40	4.00	180.00	500.00	19.00
0	0.50	1.80	15.00	14.50	0.50	4.00	180.00	500.00	16.00
0	0.20	1.40	15.00	14.50	0.40	4.00	180.00	500.00	21.00
0	0.80	1.80	15.00	14.50	0.50	4.00	180.00	500.00	15.00

HU-25A	23 FEB 83		16 FT. BOATS							
1	1.50	0.20	15.00	15.50	0.90	2.00	180.00	1500.00	50.00	-1.00
1	1.40	0.90	15.00	15.50	0.90	2.00	240.00	1500.00	53.00	-1.00
1	0.70	1.00	15.00	15.50	0.90	2.00	240.00	1500.00	53.00	-1.00
1	1.40	1.30	15.00	13.00	0.90	2.00	180.00	1500.00	43.00	-1.00
0	2.60	0.40	15.00	15.50	0.90	2.00	180.00	1500.00	51.00	-1.00
0	0.90	0.10	15.00	15.50	0.90	2.00	180.00	1500.00	50.00	-1.00
0	3.20	0.20	15.00	15.50	0.90	2.00	180.00	1500.00	50.00	-1.00
0	3.30	0.90	15.00	15.50	0.90	2.00	240.00	1500.00	53.00	-1.00
0	2.70	0.80	15.00	15.50	0.90	2.00	240.00	1500.00	53.00	-1.00
0	2.60	1.50	15.00	13.00	0.90	2.00	180.00	1500.00	42.00	-1.00
0	0.90	1.20	15.00	13.00	0.90	2.00	180.00	1500.00	45.00	-1.00
0	3.20	1.30	15.00	13.00	0.90	2.00	180.00	1500.00	43.00	-1.00
0	2.30	1.90	15.00	13.00	0.90	2.00	240.00	1500.00	36.00	-1.00
0	1.30	2.00	15.00	13.00	0.90	2.00	240.00	1500.00	35.00	-1.00
0	0.80	2.10	15.00	13.00	0.90	2.00	240.00	1500.00	34.00	-1.00
0	3.20	2.00	15.00	13.00	0.90	2.00	240.00	1500.00	35.00	-1.00

HU-25A	23 FEB 83		LIFERAFTS							
1	1.50	0.20	15.00	15.50	0.90	2.00	180.00	1500.00	50.00	2.00
1	0.20	0.40	15.00	15.50	0.90	2.00	180.00	1500.00	51.00	2.00
1	1.80	0.80	15.00	15.50	0.90	2.00	240.00	1500.00	53.00	2.00
1	1.60	0.90	15.00	15.50	0.90	2.00	240.00	1500.00	53.00	2.00
1	2.40	1.00	15.00	15.50	0.90	2.00	240.00	1500.00	53.00	2.00
0	2.00	0.40	15.00	15.50	0.90	2.00	180.00	1500.00	51.00	2.00
0	2.20	0.50	15.00	15.50	0.90	2.00	180.00	1500.00	52.00	2.00
0	2.60	0.10	15.00	15.50	0.90	2.00	180.00	1500.00	50.00	2.00
0	2.20	0.70	15.00	15.50	0.90	2.00	240.00	1500.00	53.00	2.00
0	0.00	0.80	15.00	15.50	0.90	2.00	240.00	1500.00	53.00	2.00
0	0.20	1.50	15.00	13.00	0.90	2.00	180.00	1500.00	41.00	2.00
0	2.60	1.20	15.00	13.00	0.90	2.00	180.00	1500.00	44.00	2.00
0	1.40	1.30	15.00	13.00	0.90	2.00	180.00	1500.00	43.00	2.00
0	0.00	1.90	15.00	13.00	0.90	2.00	240.00	1500.00	36.00	2.00
1	1.60	2.00	15.00	13.00	0.90	2.00	240.00	1500.00	35.00	2.00
1	2.40	2.10	15.00	13.00	0.90	2.00	240.00	1500.00	34.00	2.00
0	3.20	2.00	15.00	13.00	0.90	2.00	240.00	1500.00	35.00	2.00

HU-25A	24 FEB 83		LIFERAFTS							
1	0.50	0.70	15.00	12.00	0.90	3.00	180.00	500.00	52.00	2.00
1	0.60	0.90	15.00	12.00	0.90	3.00	180.00	500.00	51.00	2.00
1	0.30	1.50	15.00	12.00	0.90	3.00	180.00	500.00	48.00	2.00
1	0.80	1.70	15.00	12.00	0.90	3.00	180.00	300.00	45.00	2.00
1	0.50	2.20	15.00	12.00	0.90	3.00	180.00	300.00	40.00	2.00
1	0.70	2.40	15.00	12.00	0.90	3.00	180.00	300.00	37.00	2.00
1	0.30	3.00	15.00	12.00	0.90	3.00	180.00	300.00	31.00	2.00
0	0.80	0.20	15.00	12.00	0.90	3.00	180.00	500.00	53.00	2.00
0	1.20	0.00	15.00	12.00	0.90	3.00	180.00	500.00	53.00	2.00
0	1.30	2.30	15.00	12.00	0.90	3.00	180.00	300.00	38.00	2.00

HU-25A	24 FEB 83		PIW						
0	0.60	0.80	15.00	12.00	0.90	3.00	180.00	500.00	51.00
1	0.00	1.20	15.00	12.00	0.90	3.00	180.00	500.00	50.00
1	0.20	1.70	15.00	12.00	0.90	3.00	180.00	300.00	45.00
1	0.10	2.50	15.00	12.00	0.90	3.00	180.00	300.00	35.00
1	0.10	2.70	15.00	12.00	0.90	3.00	180.00	300.00	34.00
0	0.60	0.10	15.00	12.00	0.90	3.00	180.00	500.00	53.00
0	0.30	0.70	15.00	12.00	0.90	3.00	180.00	500.00	52.00
0	1.10	0.70	15.00	12.00	0.90	3.00	180.00	500.00	52.00
0	0.10	0.20	15.00	12.00	0.90	3.00	180.00	500.00	53.00
0	1.00	0.60	15.00	12.00	0.90	3.00	180.00	500.00	53.00
0	0.00	0.60	15.00	12.00	0.90	3.00	180.00	500.00	52.00
0	0.90	0.20	15.00	12.00	0.90	3.00	180.00	500.00	53.00
0	1.10	0.30	15.00	12.00	0.90	3.00	180.00	500.00	53.00
0	1.00	0.60	15.00	12.00	0.90	3.00	180.00	500.00	53.00
0	0.10	0.30	15.00	12.00	0.90	3.00	180.00	500.00	53.00
0	1.00	0.50	15.00	12.00	0.90	3.00	180.00	500.00	53.00
0	0.90	0.30	15.00	12.00	0.90	3.00	180.00	500.00	53.00
0	0.00	0.50	15.00	12.00	0.90	3.00	180.00	500.00	53.00
0	0.50	1.50	15.00	12.00	0.90	3.00	180.00	500.00	48.00
0	1.00	1.50	15.00	12.00	0.90	3.00	180.00	500.00	48.00

0	0.00	1.00	15.00	12.00	0.90	3.00	180.00	500.00	51.00
0	0.90	1.30	15.00	12.00	0.90	3.00	180.00	500.00	49.00
0	0.90	0.90	15.00	12.00	0.90	3.00	180.00	500.00	51.00
0	0.00	1.30	15.00	12.00	0.90	3.00	180.00	500.00	49.00
0	1.10	1.00	15.00	12.00	0.90	3.00	180.00	500.00	50.00
0	1.00	1.30	15.00	12.00	0.90	3.00	180.00	500.00	49.00
0	0.00	1.00	15.00	12.00	0.90	3.00	180.00	500.00	51.00
0	1.00	1.30	15.00	12.00	0.90	3.00	180.00	500.00	50.00
0	1.00	1.00	15.00	12.00	0.90	3.00	180.00	500.00	51.00
0	0.50	1.60	15.00	12.00	0.90	3.00	180.00	300.00	46.00
0	0.40	2.20	15.00	12.00	0.90	3.00	180.00	300.00	40.00
0	1.00	2.20	15.00	12.00	0.90	3.00	180.00	300.00	40.00
0	1.00	2.00	15.00	12.00	0.90	3.00	180.00	300.00	42.00
0	0.80	1.70	15.00	12.00	0.90	3.00	180.00	300.00	45.00
0	0.00	2.10	15.00	12.00	0.90	3.00	180.00	300.00	41.00
0	1.20	1.80	15.00	12.00	0.90	3.00	180.00	300.00	44.00
0	1.00	2.10	15.00	12.00	0.90	3.00	180.00	300.00	42.00
0	0.20	1.80	15.00	12.00	0.90	3.00	180.00	300.00	44.00
0	1.00	2.00	15.00	12.00	0.90	3.00	180.00	300.00	42.00
0	0.80	1.80	15.00	12.00	0.90	3.00	180.00	300.00	44.00
0	0.00	2.00	15.00	12.00	0.90	3.00	180.00	300.00	42.00
0	0.60	2.30	15.00	12.00	0.90	3.00	180.00	300.00	38.00
0	0.40	2.90	15.00	12.00	0.90	3.00	180.00	300.00	31.00
0	1.00	2.90	15.00	12.00	0.90	3.00	180.00	300.00	31.00
0	0.10	2.50	15.00	12.00	0.90	3.00	180.00	300.00	37.00
0	1.10	2.80	15.00	12.00	0.90	3.00	180.00	300.00	33.00
0	1.10	2.70	15.00	12.00	0.90	3.00	180.00	300.00	34.00
0	0.90	2.50	15.00	12.00	0.90	3.00	180.00	300.00	36.00
0	0.10	2.90	15.00	12.00	0.90	3.00	180.00	300.00	32.00
0	0.90	2.40	15.00	12.00	0.90	3.00	180.00	300.00	37.00
0	1.00	2.80	15.00	12.00	0.90	3.00	180.00	300.00	33.00

APPENDIX B

FLAR SEARCH RAW DATA

This appendix contains raw data files for daily FLAR searches. The following is a key to the format of the data:

Column 1:	Detection (1 = yes, 0 = no)
Column 2:	Range from start of search leg to target (nautical miles)
Column 3:	Range of detection/closest point of approach for miss (nautical miles)
Column 4:	Radar range scale (nautical miles; 0 denotes unknown)
Column 5:	Wind speed (knots)
Column 6:	Significant wave height (feet)
Column 7:	Precipitation (0 = none; 1 = light/moderate rain; 2 = heavy rain)
Column 8:	Relative humidity (percent)
Column 9:	Relative wave direction (-1 = not recorded; 0 = opposite vessel course; 1 = with vessel course; 2 = perpendicular to vessel course)
Column 10:	Target type (see below)
Column 11:	Search speed (knots)
Column 12:	Altitude (feet)

FLAR TARGET TYPES

1 - indicates 16-foot fiberglass boat without radar reflector
6 or 8 - indicates 16-foot fiberglass boat with radar reflector
30 - indicates 4- to 6-man canopied life raft

HU-25A	AN/APR-127		FLAR	10 FEB 83								
0	3.30	0.20	10.00	19.00	4.50	0.00	74.00	1.00	1.00	180.00	300.00	1.00
0	3.40	0.10	10.00	19.00	4.50	0.00	74.00	2.00	30.00	180.00	300.00	1.00
1	6.20	2.50	10.00	19.00	4.50	0.00	74.00	0.00	30.00	180.00	300.00	1.00
0	16.50	0.20	10.00	19.00	4.50	0.00	74.00	0.00	1.00	180.00	300.00	1.00
0	8.30	0.00	10.00	19.00	4.50	0.00	74.00	1.00	6.00	180.00	500.00	1.00
0	2.00	0.00	10.00	19.00	4.50	0.00	74.00	2.00	30.00	180.00	500.00	1.00
0	4.00	0.00	10.00	19.00	4.50	0.00	74.00	2.00	1.00	180.00	500.00	1.00
1	3.20	3.20	10.00	19.00	4.50	0.00	74.00	2.00	30.00	180.00	500.00	1.00
0	4.5[illegible]	0.10	10.00	19.00	4.50	0.00	74.00	1.00	1.00	180.00	1000.00	1.00
0	3.40	0.00	10.00	19.00	4.50	0.00	74.00	2.00	30.00	180.00	1000.00	1.00
0	3.90	0.40	10.00	19.00	4.50	0.00	74.00	2.00	1.00	180.00	1000.00	1.00
0	1.90	0.30	10.00	19.00	4.50	0.00	74.00	0.00	30.00	180.00	1000.00	1.00

HU-25A	AN/APR-127		FLAR	15 FEB 83								
0	3.50	0.30	5.00	8.50	4.50	0.00	76.00	0.00	1.00	180.00	300.00	1.00
1	9.40	3.10	5.00	8.50	4.50	0.00	76.00	2.00	30.00	180.00	300.00	1.00
0	4.90	0.60	5.00	8.50	4.50	0.00	76.00	2.00	30.00	180.00	300.00	1.00
0	12.60	0.10	5.00	8.50	4.50	0.00	76.00	2.00	1.00	180.00	300.00	1.00
0	13.50	0.30	5.00	8.50	4.50	0.00	76.00	1.00	1.00	180.00	300.00	1.00
0	16.10	0.20	5.00	8.00	4.50	0.00	76.00	0.00	30.00	180.00	500.00	1.00
0	9.10	0.20	5.00	8.00	4.50	0.00	76.00	2.00	30.00	180.00	500.00	1.00
0	4.00	0.70	5.00	8.00	4.50	0.00	76.00	2.00	30.00	180.00	500.00	1.00
0	11.70	0.00	5.00	8.00	4.50	0.00	76.00	2.00	1.00	180.00	500.00	1.00
0	9.70	0.40	5.00	8.00	4.50	0.00	76.00	1.00	1.00	180.00	500.00	1.00
0	16.00	0.20	5.00	5.[illegible]	3.50	0.00	72.00	0.00	30.00	180.00	300.00	1.00
0	10.50	0.20	5.00	[illegible].50	3.50	0.00	72.00	2.00	30.00	180.00	300.00	1.00
0	4.70	0.60	5.00	[illegible].50	3.50	0.00	72.00	2.00	30.00	180.00	300.00	1.00
0	12.30	0.00	5.00	[illegible].50	3.50	0.00	72.00	2.00	1.00	180.00	300.00	1.00
0	11.20	0.30	5.00	5.50	3.50	0.00	72.00	1.00	1.00	180.00	300.00	1.00
0	11.10	0.30	5.00	5.50	3.50	0.00	72.00	0.00	30.00	180.00	500.00	1.00
0	8.30	0.20	5.00	5.50	3.50	0.00	72.00	2.00	30.00	180.00	500.00	1.00
0	8.20	0.70	5.00	8.00	3.50	0.00	68.00	2.00	30.00	180.00	500.00	1.00
0	16.00	0.00	5.00	8.00	3.50	0.00	68.00	2.00	1.00	180.00	500.00	1.00

HU-25A	AN/APS-127		FLAR	25 FEB 83								
1	14.00	2.00	5.00	8.00	1.50	0.00	52.00	-1.00	8.00	180.00	300.00	1.00
0	4.70	0.10	5.00	8.00	1.50	0.00	52.00	-1.00	30.00	180.00	300.00	1.00
0	11.60	0.00	5.00	8.00	1.50	0.00	52.00	-1.00	8.00	180.00	300.00	1.00
0	7.70	0.20	5.00	8.00	1.50	0.00	52.00	-1.00	30.00	180.00	300.00	1.00
1	10.70	1.40	5.00	8.00	1.50	0.00	52.00	-1.00	8.00	180.00	500.00	1.00
0	1.80	0.30	5.00	8.00	1.50	0.00	52.00	-1.00	30.00	180.00	500.00	1.00
0	8.90	0.00	5.00	8.00	1.50	0.00	52.00	-1.00	8.00	180.00	500.00	1.00
0	6.90	0.30	5.00	8.00	1.50	0.00	52.00	-1.00	30.00	180.00	500.00	1.00
1	6.[illegible]0	1.80	5.00	8.00	1.50	0.00	52.00	-1.00	30.00	180.00	500.00	1.00
1	6.50	2.10	5.00	12.00	1.50	0.00	55.00	-1.00	30.00	180.00	500.00	1.00
1	18.20	1.80	5.00	12.00	1.50	0.00	55.00	-1.00	8.00	180.00	500.00	1.00
0	11.20	0.20	5.00	8.00	1.50	0.00	52.00	-1.00	30.00	180.00	500.00	1.00
0	11.40	0.00	5.00	12.00	1.50	0.00	55.00	-1.00	8.00	180.00	500.00	1.00

APPENDIX C

METRIC CONVERSION FACTORS

1. <u>Feet to Meters</u>

1 foot = 0.3048 meters

Thus:

3 to 4 foot swells ≈ 1 meter swells,
a 16-foot boat ≈ a 5-meter boat, and
an altitude of 500 feet ≈ a 150 meter altitude.

2. <u>Nautical Miles to Kilometers</u>

1 nautical mile (nm) = 1.852 kilometers (km)

Thus:

10 nm visibility ≈ 18.5 km visibility, and
a 2 nm range ≈ 3.7 km range.

3. <u>Knots to Meters/Second and Kilometers per Hour</u>

1 knot = 0.5144 meters per second
1 knot ≈ 1.852 kilometers per hour

Thus:

a 10-knot wind speed ≈ 5 meter per second wind speed,
and a 10-knot search speed ≈ 18 kilometer per hour search speed.